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Dissolved Oxygen in Water and its Significance

Chemistry
B. S.

1901

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Dissolved Oxygen in Water and Its Significance

BY HOWARD TYLER GRABER

THESIS

FOR THE

Degree of Bachelor of Science in Chemistry

IN THE

COLLEGE OF SCIENCE

UNIVERSITY OF ILLINOIS

1901

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

H. T. Graber

ENTITLED Dissolved Oxygen in Water and its significance

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE

OF B. S. in Chemistry.

Arthur W. Palmer.

HEAD OF DEPARTMENT OF Chemistry.

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For many years a high standard of purity for drinking waters has been rigidly insisted upon; mainly on account of the pathogenic or disease producing germs contained in a polluted water.[1] We cannot expect to find the effect of impure water always sudden and violent. The results of the continual imbibition of polluted waters are, indeed, often gradual, and may elude ordinary observations, yet be found not the less real and appreciable by close inquiry. It is a well authenticated fact that cholera breeds in impure and polluted waters.[2] On the authority of Sir William Lawrence, Bethlem Hospital and the "House of Occupations," of London, containing 700 persons were supplied with water from a deep well sunk upon the premises in 1825. Sir W. says, "there was not a single case of cholera in the hospital or House of Occupations during the severe epidemics of 1832, 49, or 52; although the immediate surrounding neighborhood suffered severely. Again, on the authority of Surgeon Major

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A. C. — de Lenzy, the inventor of Belmont's prison, suffered severely from cholera in the epidemics of 1832 and 1849, both being ascribed to impure water. In the next cholera epidemic of 1854 the prisoners were again attacked, for the disease was at once epidemic by changing the water supply. The change was made in the midst of the severe epidemic, & a very abundant well. Fix ups with the change the disease entirely stopped, and a marked improvement took place in the health of the prisoners, and it is a matter of history that in the twenty years since the change there has been but one death from diarrhoea and dysentery. In fact it is only when such striking and potent effects as these are produced, that public attention is excited, and interest in the water supply is renewed. The not less certain evils are borne with the indifference of the habit. Although no disease may be produced during the life of a man by the habitual use of an impure water, yet there can be no question but that impure drinking water, effects the physique of individuals and tends to the degeneration of the race. (3) The question of wholesomeness of a

water lingers mainly upon the presence or absence of putrescent matter, as they themselves are the cause of the derangements of the human system. Most serious forms, are the consequences when the low forms of organic life which, in all probability form the specific poisons of cholera, typhoid fever, and other diseases gain admission to drinking waters polluted with putrescent matter. A number of observations point to the conclusion that these organisms, or their germs, are not injurious as long as they are surrounded by fresh organic matter, for as soon as fermentation sets in they show their poisonous virulence. Thus it has been found that the discharge of cholera and typhoid patients are not injurious as long as they are fresh. For this reason the determination of the condition of the organic matter becomes a very important one. But proper care only exercised in every point in the analysis of waters can give such information as required. The presence or nonpresence of a water for drinking purposes, will, as before said, it is also quite evident that the danger, more or less is due, due however to what the chemists term "organic matter"; and that there are times when that organic matter

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is in a more true and genuine state.

The point of difficulty in the examination of this organic matter is not so much its quantitive determination as its character; for you may have a water rich in organic matter, yet harmless, or a water containing but a minimum of organic matter, the most poisonous character. Therefore our opinion as to the state of the organic matter, water, if it has any, is to be in the chemists hands only, by the united aid of the two together of many analyses, for chemical analysis is incapable, at its present stage of discriminating between living and dead, fresh or putrescent organic matter. So frequently how poor opinion is the determination of organic matter in a water it may be well to say that it is only after the following determinations have been made that an opinion concerning the nature of the organic matter can be given. The determinations are 1st. Organic carbon, 2nd. Organic nitrogen, 3rd. Organic carbon + nitrogen, 4th Nitrogen as free ammonia, 5th Nitrogen as albuminoid ammonia, 6th Nitrogen as total ammonia, 7th Oxygen consumed by acid $KMnO_4$ in 1 hour and 8th Oxygen consumed by $KMnO_4$ in three hours.

To summarize our results we must take into consideration the quality of the organic matter, that is, we must determine what is produced in the water by its standing under favorable conditions for the growth of vegetable or other life, we must determine the presence of decomposition, if considerable decomposed organic matter is present we must determine nitrites as compared with organic nitrogen, nitrates from the same source, chlorides indicating contamination from animal matter, total organic matter and ammonia by weighing and these methods and decide the amount of "Dissolved Oxygen" present as indicating the activity of decomposition or disinfection.

The most valuable method of examining a water to determine the relative condition of the organic matter present is undoubtedly to be found in the determination of the relative amounts of oxygen present; for if the air dissolved in a water is found to contain less oxygen than its normal amount, it, of course, shows that this element is being consumed by chemical changes going on within the water, or, in other words such a water is not in its normal state and therefore is unfit for general use, for in judging of the character of a water for domestic use,

One of the most important points to be determined is whether it is or is not polluted by sewage and other deleterious substances. This contamination exists in a two-fold effect upon all the various forms of life found in solution in the water and especially upon the oxygen present.

The oxygen dissolved in water comes chiefly from two sources. Part of it is derived from the air, but some of it comes from the oxygen liberated by vegetable growth in the water. This latter oxygen being liberated from the surface of the water is usually found in greatest quantity on the surface under the water so directly exposed.

It is evident, under these facts, that the relative quantity of oxygen present in a water affords a key to its determination by organic matter; because it is unlikely that a large quantity of oxygen can be found in solution by a water containing oxidizable matter. Where much sewage flows into a stream the oxygen in solution is lessened, and other gaseous constituents must be expected as free from sewage and decaying matter, as diminished in the above said quantity would indicate the presence of such pollution.

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Pure water may contain but a large amount of oxygen and but a good quantity of organic matter, for if the water is polluted in contact with air it absorbs the oxygen quite readily; and if animals are taken from the organic matter they find ample opportunity to consume the oxygen, however will their large amounts of fish to be present, etc. so the same time the fish are to be distributed two months in which amount of water in the fish aquariums, determining the amount of carbonic acid water present at the time of collecting and then setting the water aside. Similar periods of 24, 48, 96, etc. hours before determining if any increase or diminution in the relative amounts of oxygen present has taken place. Again deep well water with very little nutrient organic matter, contain little or no dissolved oxygen, but the diminution or lack is due to its existing and developing the organic matter in its passage through the strata.

In general, concerning the oxygen & air dissolved in water. I will quote passages from various writers. (6) Hermann and Blanc "The existence of a water in aerate to the destruction of organic matter, a diminution in the quantity

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"4. Bacteria or any low form of organic matter and putrefaction. Putrefaction is associated with the development of these organisms like, among disagreeable taste and smell."

"5. Thus, if the dissolved oxygen is high it indicates that there is little organic or oxidizable matter present or that the organic matter is not decomposing, if low it indicates that organic matter has accumulated in the form of decomposing or that organisms have absorbed it; for bacteria require oxygen for their growth and absorb it from the water."

"But the real science of sanitation is dealing with the organic matter of the water and little effort is spent in studying its organisms, bacteria, etc. present. Hence we see how unsatisfactory this method of investigation is."

"In general, however, for the interpretation of results obtained from the dissolved oxygen determination, the following statements have been made, viz: a water which does not deteriorate in its power of digestion during a given time may or may not contain organic matter, but certainly does not contain many organisms."

"Such organic matter may be found not to be considered dangerous, while a water which,

by heat, or by the addition of certain reducing reagents, from the dissolved air, at ordinary temperatures, but does not evolve any after boiling for 3 hours at 170° F., may be regarded as having contained during evaporation that could survive 170° F., such water would always be boiled for a long time before using, and water which upon the addition of solution of the colorimetric medium continues to exert its full color when contained air still heating to 170° F. may be taken as satisfactory, others or which the air turnful.

(9) Determinations of the nitrogen in the soil and nitrates present in plant growth are for in the presence of deoxidizers, are standard organic matter, and in the absence of sufficient dissolved oxygen for the growth of bacteria and the nitrates are reduced to nitrites and ultimately to free nitrogen, some active bacteria even preferring the oxygen in nitrates to that dissolved in the water.

It is a matter of history that about twenty years ago free oxygen in water was estimated by means of nitric oxide, and that by this

Winkler's titrated results which were inaccurate and variable. Into a solution, Winkler obtained almost 2 c.c. which he came results for the oxygen of the air as Bunsen and more modern workers who have employed the method of extracting a mixture of nitrogen and oxygen. The question, of course, arose how came it to pass that Winkler could get results so erroneous, whilst other experimenters working at the same date and using the same method obtained concordant and accurate results? The answer is evident. His results were obtained correctly when the conditions were right, but when the conditions were not complied with the method failed. Thus in (1) the saturation of the mixed oxygen had to be accomplished by means of a very troublesome and time taking process, in consequence of which this important feature of water analysis was universally neglected. (2) Andrews, Schützenberger and Gies later described an important source of error in which they made use of the reducing power of an acid discovered by Schützenberger in 1869 and called by him hydrosulphurous acid. Now hydrosulphurous passes to thiosulphuric or dithionous acid.

11. By the help of the volumetric and the iodometric estimation of the oxygen dissolved in water became at once easy and rapid. Thus was the beginning of our present methods and the many variations and improvements were followed.

In general the methods for the determination of dissolved oxygen may be divided into two great classes. First the Gas-volumetric and secondly, - the Titration methods.

To the first class, the gas volumetric, not much need be said for, on account of the numerous and obvious advantages, in a rapid determination. The method is seldom used. Nevertheless, these methods, when correctly executed are very accurate and sensitive.

The theory in general on the methods consists essentially, in fixing on the dissolved gas in a measured volume of water, and collecting and measuring the O_2 so fixed determined by absorption in $CuCl$. The interval between is an unfavorable solution while the oxygen is absorbed by ferrous (10) hydrate ($Fe_2O_6H_6$) and its volume measured by titration with hydrogen.

In 1891 Winkler devised the theory of the use of the oxygen pipette and took [illegible]

with ammonium permanganate.

In the same year a notice is given in the "Fortschritte der Chemie" which states that oxygen, obtained by boiling water containing an ammoniacal solution of protoxide of iron, and filtering the yellow ferric iron, with many milk acid added "Chandelon."

On p. 550, vol. 5, of the Journal there gives a method for preparing chromous chloride, made by reducing chromic chloride with zinc. This chromous chloride is a strong oxygen absorber.

The method of [illegible], given in detail in the Journal of the Chemical Society, Vol. 47, p. 75, is not suited for all purposes. It requires a considerable time. The reagents and the solutions are very unstable. The method depends upon the fact that a solution of sodium hydrosulphite (Na2S2O4) immediately absorbs oxygen and more rapidly than the bisulphite. Sodium salts differs from the hydrosulphite by containing but one atom more of sodium, has no effect upon the oxygen. The hydrosulphite in the presence of free oxygen immediately yields to the

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[illegible] by hydrogen and are then oxidized to the [illegible] and [illegible].

On the Journal of the American Society for 1880, page 185, a method is given by E. [illegible] which is intended to estimate the ammonia in the form of salt, the method consists in mixing a little lead with a few cubic centimeters of the liquid, and evaporating to dryness, into the dish. A platinum funnel is placed upon the dish and a little dilute sulphuric acid poured through the funnel. Crystals of lead sulphate collect on it & [illegible] with the remaining lead. Crystals and funnel are [illegible] with H.C.l. & a drop of nitric acid and [illegible] with dilute ammonia until the lead sulphate dissolves. The solution of platinum and the [illegible] quickly replaced.

The dish is placed [illegible] water for fifteen minutes after which a current of air is drawn through the dish. The [illegible] of platinum is now added to the solution and the [illegible] evaporated over the H.C.l. &, [illegible]

is present and the titration completed.

(12) In 1891 J. C. Thresh announced a method the principle of which is that in the absence of oxygen nitrous acid and hydriodic acid react to form iodine, water and nitric oxide. But that in the presence of free oxygen, the nitric oxide becomes re-oxidized again, acting as a carrier of the oxygen, and amount of iodine is liberated equivalent to the oxygen present, in addition to that resulting from the nitrous acid; hence deducting that liberated by the nitrous acid from the oxygen dissolved in the original solution used for the whole amount, the difference is that due to the oxygen dissolved in the water.

(13) In 1887 Albert Levy modified the above method. He treated the water with strong hydrochloric acid in the presence of nitric oxide, then neutralized the acid with potassium bicarbonate and estimated the liberated iodine by means of 1/10 arsenious acid.

C. Quinche gives a method in the J. of the Soc. of Chemical Industry, vol. [illegible]. The principle depends upon the oxidation of ferrous tartrate to ferric tartrate in an alkaline solution and the disappearance of the [illegible]

color due to phenosafranine in the presence of free ferrous sulfate. The solution of ferrous sulfate to be titrated under consideration, phenosafranine being used as the indicator, and as soon as the red oxygen dichloride had the first trace of ferrous sulfate decolorized the liquid.

The following method is given in Treadwell's Analytische Chemie. The first of the determinations in this method is the amount of ferrous sulfate equivalent to the dichromate solution to be used in the titration of the solution containing the ferrous salt to be determined.

The apparatus used is a 250 cc. flask, a 25 cc. pipette calibrated to contain 10 c. c. and fitted with two glass cocks. To the outlet end of the pipette a rubber tubing is attached, while the other end is drawn out into a point which has been ground to a fine orifice.

The reagents necessary for the determination are: a solution of ammonium ferrous sulfate containing 20 grams of the crystallized salt in a litre. A 10% solution of sulfuric acid, 50 c. c. of a solution of $K_2Cr_2O_7$ containing 1.61 grams and a 2% solution of starch paste. Into each of three 250 c. c.

17.

By the estimation equals one part of ammonia for every million parts of water, when titrating 100 c.c. samples. It is essential air enters the tube connects to the tube in the bottle that no air is admitted into the bottle.

The method of procedure is as follows.

Fill the bottle with the water to be tested taking care that no air bubbles are left. Add 2 c.c. of the caustic potash solution to the funnel. Open the screw cock and allow sufficient from the upper one and allow the KOH. to enter the bottle, closing the cock before air is allowed to enter the bottle. Next rinse out the funnel two or three times with distilled water, and then add 2 c.c. of the ammonium sulphate solution into the funnel. Add 5 c.c. of the Nessler solution to the water to be used for the analysis and after closing the screw cock, shake the bottle to cover the surface of the acid with the water. This precipitates the water formed if any present by simple filtration to pass through the bottle, at the stage of the analysis and not air is allowed to enter the bottle and should be noted that the presence of the air would have little effect upon it

Open the water cock and allow the water to flow out slowly against the entrance of air. Now both cocks are open the bottle is inverted repeatedly, pressure once, so that all of the water comes in contact with the reagents. Allow to stand until the precipitate settles. In the presence of an alkaline solution the oxygen dissolved in the water oxidizes some ferrous hydrate to ferric hydrate and a portion of the air enters with it. Shake mixture once and allow to settle. Add 5 c.c. of the sulphuric acid, then 2 c.c. of the caustic potash, 5 c.c. of the ammonium ferrous sulphate solution 20 c.c. of distilled water to equal that added to wash out pipette and titrate with the permanganate solution, the amount of oxidation of ferrous salt caused by dissolved oxygen is determined in this flask as the dissolved oxygen has no effect on the ammonium ferrous sulphate in the dead solution.

After the bottle has stood about five minutes add 5 c.c. of the $N_2 SO_4$ to the funnel and open the water cock only, the acid being of greater density than the water, does not

19 into the water, discharging it [illegible] the precipitate of ferrous and ferric hydroxide without exposing the contents to air. When the solution in the pipette is [illegible], then the lower cock and allow the contents of the pipette to flow into a beaker. Rinse out the pipette with 25 c.c. distilled water. Titrate with permanganate as quickly as possible, especially if water is contaminated with organic matter, and take first indication of change as the end reaction as organic matter exerts a reducing action upon the permanganate.

This latter titration gives us the amount of oxidation due to the dissolved oxygen and subtracting this from the blank gives us the amount of ferrous salt oxidized [illegible] by the dissolved oxygen in the water.

The reactions are as follows

$(NH_4)_2Fe(SO_4)_2 + 2NaOH = Fe(OH)_2 + (NH_4)_2SO_4 + Na_2SO_4$

in the presence of oxygen

$Fe(OH)_2 + H_2O + O = 2Fe(OH)_3$

unoxidized $Fe(OH)_2 + H_2SO_4 = FeSO_4 + 2H_2O$

$10FeSO_4 + K_2Mn_2O_8 + 8H_2SO_4 = 5Fe_2(SO_4)_3 + K_2SO_4 + 2MnSO_4 +$ [illegible]

The description of the test method here described is found in the Berichte der Deutschen Chemischen Gesellschaft for 1888, p. 2843.

The dissolved oxygen in the water will readily oxidize manganous hydroxide to manganic hydroxide, and this manganic hydroxide in the presence of potassium iodide and hydrochloric acid will liberate iodine and be reduced to manganous chloride. The liberated iodine is titrated with sodium thiosulphate using a starch indicator.

The only special apparatus necessary is a bottle of known capacity that can be closed air tight. The solutions necessary are one-eighth normal solution of sodium hydroxide, a solution of 40 grams of pure manganous chloride in 100 c.c. of water, a starch solution, crystallized potassium iodide, hydrochloric acid of sp. gr. 1.20 and [illegible] thiosulphate solution.

The method is as follows. Fill the bottle with water to be tested, add 1 c.c. of a sodium hydroxide + potassium iodide solution by means of a long pipette calibrated so as to be able to add the solution to the bottom of the bottle and have solution enough above the level of the water in the bottle to force the 1 c.c. out of the pipette. Now add 1 c.c. of the manganous chloride solution, stopper tightly and mix

chromate. The nitrate and also the H_2 must be free from NH_4 which are frequently present in the reagents. Add to the precipitate two cubic c.c. and 5 c.c. of the conc. hydrochloric acid warm the acid so as to come in contact with precipitated Fe_2-hydroxide. Decant the acid and wash again, let stand until all the precipitate has dissolved. The ferric hydroxide is changed to ferrous chloride which reacts with the KI of the KI and liberates iodine. The amount of iodine liberated being directly proportional to the amount of manganese dioxide present, and therefore directly proportional to the amount of iron present in the water. For the analysis of the water use a liter flask, fill nearly full with 25 c.c. of distilled water. Titrate with $\frac{N}{100}$ $Na_2S_2O_3$ using starch as an indicator. In this method use a flask like directions for the Kjeldahl flask. Take 500 c.c. of distilled water, add 10 c.c. of ammonium hydroxide without CO_2 and 10 c.c. of the manganese chloride, stir well, filter, and wash the precipitate — 2 or 3 c.c. of fuming hydrochloric acid making the solution up to definite volume by means of distilled water.

To the manganese chloride solution, as a factor, as was, used as directed in the distilled water and in their place 100 c.c. of the sodium acid sulphate solution to which the manganese chloride solution is added, also to about the same acidity as the solution and titrate by means of the $KMnO_4$ using starch as an indicator. Subtract the difference between the readings of the water and the water solution and add this amount to the amount of the thiosulphate used for the determination of oxygen when calculating to parts per million.

The reaction for this method follows:

$$MnCl_2 + 4NaOH = 2NaCl + Mn(OH)_2$$

$$2Mn(OH)_2 + O_2 = 2MnO_2 + 2H_2O$$

$$2MnO_2 + 8HCl = 2MnCl_4 + 4H_2O$$

$$MnCl_4 = MnCl_2 + Cl_2$$

$$2KI + 2Cl_2 = 2KCl + I_2$$

$$2Na_2S_2O_3 + I_2 = Na_2S_4O_6 + 2NaI$$

This method was tried for sewage, but it was unsuccessful. The high results are due to the oxidation of the hydriodic acid liberating iodine according to the equation.

$$4HI + O_2 = 2I_2 + 2H_2O$$

This liberates iodine contained and made

solution, due to the action of the air, and
action, by means of the organic matter.

In order to accomplish the results aimed
at we had to obtain a method which would
secure the water entirely free from organic matter
case and the effect of such organic matter
upon the dissolved oxygen we contained in
a large coil. It was first necessary to find
a method which would remove the organic matter
from the water without affecting the dissolved oxygen in the
water." To this end a test known as the
"Kinetic" or Permanganate method was used.

On the 21st of November, 1900, I went to the machine shop of the Lowell Machine Co. and procured the water cock and old street railway line, and collected two gallons of water.

The temperature of the water was 10° C. The water was taken to the laboratory, thoroughly shaken to a foam with air, mixed, and twelve glass stoppered bottles were filled with it.

The bottles had been previously calibrated by weighing the weight of the empty bottles, then the weight of the bottle filled with H₂O, and assuming that one gram of water occupies the volume of one cubic centimeter at 15° C, I have

[illegible] meters, as volume. [illegible] means of an [illegible] of rubber tubing [illegible] Large test and at either end a glass [illegible] one at the [illegible] the other end. By means of this apparatus water was carried from the air and forced into the bottles and as the bottle contents were progressively absorbed some of this was

To avoid making a correction for gases remaining more readily than was theoretically obtained in the water, this water should [illegible] into the bottle was completely displaced. For this purpose all bottles with the rubber stopper [illegible] at 11 A.M.

Ten of the bottles were now carefully withdrawn as we are not to have any air further [illegible] the water. To the other two bottles, i.e. of a 89% sodium hydroxide solution containing 1% of potassium iodide and 1% sodium [illegible] then 1 c.c. of a manganous chloride solution made by dissolving 400 grams in water and diluting to 1 litre. 1 c.c. of this solution was equivalent

The solutions were brought together near the [illegible] of the bottle, which was [illegible] with the

another array [illegible]

[illegible] by means of two long narrow
detritus tubes 1 c.c. and shown [illegible]
that the end reached the bottom of the
little tube, c.c. next was [illegible]
surface of the coverage.

The weight of the potassic air the [illegible]
store the water forced the magnesia into the
little tube and decreased [illegible] c.c. of the contents, c
volume equal to the amount of magnesia
added. Having added the magnesia, im-
mediately corked the tube, excluding all
air bubbles, shook them gently [illegible] mixed
and let them stand undisturbed for five
minutes. The manganous chloride reacts with
the potassium hydrate and produces a white
curdy precipitate of Manganous hydrate
which, on the presence of free oxygen in the
water is oxidized to manganic hydrate.

After standing five minutes the precipitate
had settled completely and [illegible] c.c. of
fuming HCl was allowed to run down the
inside of the tube, bringing the strong acid
in contact with the precipitate. It was
shaken till all the brown precipitate
had disappeared and about the little water at the [illegible]

Mn Cl$_2$ 4 H$_2$O were dissolved, 1 cc. of the solution dissolved in the water added & heated to find free chlorine present in the reagent, making the solution an exact test.

The oxidized manganic hydrate or dioxide is now dissolved in hydrochloric acid; the potassium iodide solution treated with the H Cl & free chlorine, & the liberated iodine titrated according to the equation Mn Cl$_2$ + H$_2$O = Mn O$_2$ + 2 H Cl + 2 H. The contents of the bottle were poured into a beaker, the bottle being washed with twenty five c.c. of water, 1 c.c. of a standard potassium iodide solution added and the blue solution titrated to colorless with N/10 Na$_2$ S$_2$ O$_3$ + 5 H$_2$O solution.

A blank must be run on the water since the method is affected by the presence of nitrates and such organic material as will reduce iodine and liberate hydriodic acid H I + H I O$_3$ = 3 I + H$_2$O or H O, and organic matter takes up some chlorine, also oxides to correct for this the following method would be, a sample of water is treated by adding 1 c.c. of the Mn Cl$_2$ solution and 1 c.c. of a 33 % Na OH solution

a 500 c.c. of distilled water, and dilute to 1 litre. Transfer to a wash bottle, and mushed, dissolved the precipitate in conc. HCl, diluted it to 100 c.c. and mixed. To 10 c.c. of the water to be tested add 100 c.c. of the above $Na_2S_2O_3$ solution, then an excess of KI, HCl and titrate the liberated iodine with $N/100$ $Na_2S_2O_3$ as in the above.

The difference between these titrations of the distilled water and the average must be corrected to be added for every 100 c.c. of water used. Now since 1 c.c. of $N/100$ $Na_2S_2O_3$ or I_2 solution is equivalent to 0.0003175 grams of oxygen or 0.000222 c.c. at 0° and 760 m.m. pressure, if n = the ordinary titration; n_1 the number of c.c. of solution used in the first titration; n_2 the correction to be added for the exact volume of water and we have x, the volume of dissolved oxygen per litre of water then:—

$$x = \frac{0.000222 \, n + n_2 \times 100}{v - 2}$$

number of cubic centimeters per litre or

$$x_1 = \frac{0.99775 \, n - n_2 \times 100}{v - 2}$$

the number of milligrams dissolved per litre.

litre of water. By diluting the sewage and comparing it with the standard solutions the amounts of oxygen in standard solutions at various temperatures, the percentage of saturation was obtained by dividing the milligrams found in the solutions by the amount at the water temperature.

The nitrites and free ammonia without distillation were also determined. The nitrites by comparing the pink color produced by each of sulphanilic acid and naphthylamine hydrochloride solutions with standard ones. The free ammonia by the addition of Nessler's solution and comparing the brown color produced with the color produced in a solution of known ammonia content.

Winkler Method

Date of Collection	Date and hour of Examination	Temperature when Collected	Parts dissolved Oxygen	Percentage Saturation	Nitrites	Free Ammonia
Nov. 21st.	11:00 A.M. Nov. 21st	16°C	7.889 7.693	78.35 77.39	0.533	14.0
" "	11:00 A.M. Nov. 22nd.	"	"High nitrites interfered."		2.25	12.0
" "	11:55 A.M. Nov. 23rd	"			3.00	
" "	12:00 A.M. Nov. 24th.	"			4.00	

This was succeeded by the Winkler method the first day and the table shows that on that day the water contained 0.5 parts Nitrogen as Nitrite per million parts of water, and 14 parts nitrogen as free ammonia.

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next day the flask was removed to the incubator as previously as it was labeled with the sodium fluoride and the tests as before by the table. On this day the nitrites had increased from 1.5 to 2.25 parts and the free ammonia had decreased to 2.0 parts per million. These results indicate that this method cannot be used for sewage or any other water which contains 2.25 or more parts N. as nitrites per million.

At 2 P.M. of this same day (Nov. 21st) I filled 12 bottles with tap water, setting the water over night to bring it to room temperature as above stated. Two bottles were tested immediately and the remainder were set aside in stand periods of 24, 36, 48, 72 hours, the object being to note the rate of increase of the dissolved oxygen in water [illegible]

Winkler Method

Date of Collection of Sample.	Date and hour of Examination	Temperature when Collected	Parts dissolved Oxygen per Million	Percentage Saturation	Nitrites	Free Ammonia
	4:20 P.M.		1.49	15.36		
Nov. 21st	Nov. 21st.	17°C	1.72	17.69	0.0	Not determined
	12:20 A.M.		1.12	11.57		
"	Nov. 22nd	"	1.12		0.0	" "
	11:35 A.M.		0.41	4.26		
"	Nov. 23rd.	"	0.41		0.0	" "

The results from sewage other than was the tests made as used by the cities of San Jose

and Fostoria does not contain any nitrites, they then contain a good deal of oxidizable organic matter, for the above bath shows that, while chlorides were the same the amount of dissolved organic ammonia was nearly the same.

The Fostoria all [illegible] of chemical analysis which shows the water to contain large quantities of iron and organic matter.

The Tidy method was next used for oxygen determination. Dissolved 0.3953 grams of pure potassium permanganate in a litre of water and mixed thoroughly. The solution is of such strength that 1 c.c. consumed in the titration of 100 c.c. of water represents 1 part per 1000 parts of water. The [illegible] and all subsequent solutions of it was standardized against iron wire, using an upright Erlenmeyer flask fitted with a rubber stopper through which a straight glass tube is passed fitted with an india-rubber slit valve which allows gas or steam to pass out, but closes by atmospheric pressure when the ebullition ceases. Dilute sulphuric acid was the solvent used.

At 2 P.M. Nov. 21st, the six large carboys which were cleaned were filled with water from the manhole behind the water plant.

31

The temperature of the sewage water was taken to the laboratory, a clear creek and filtered through

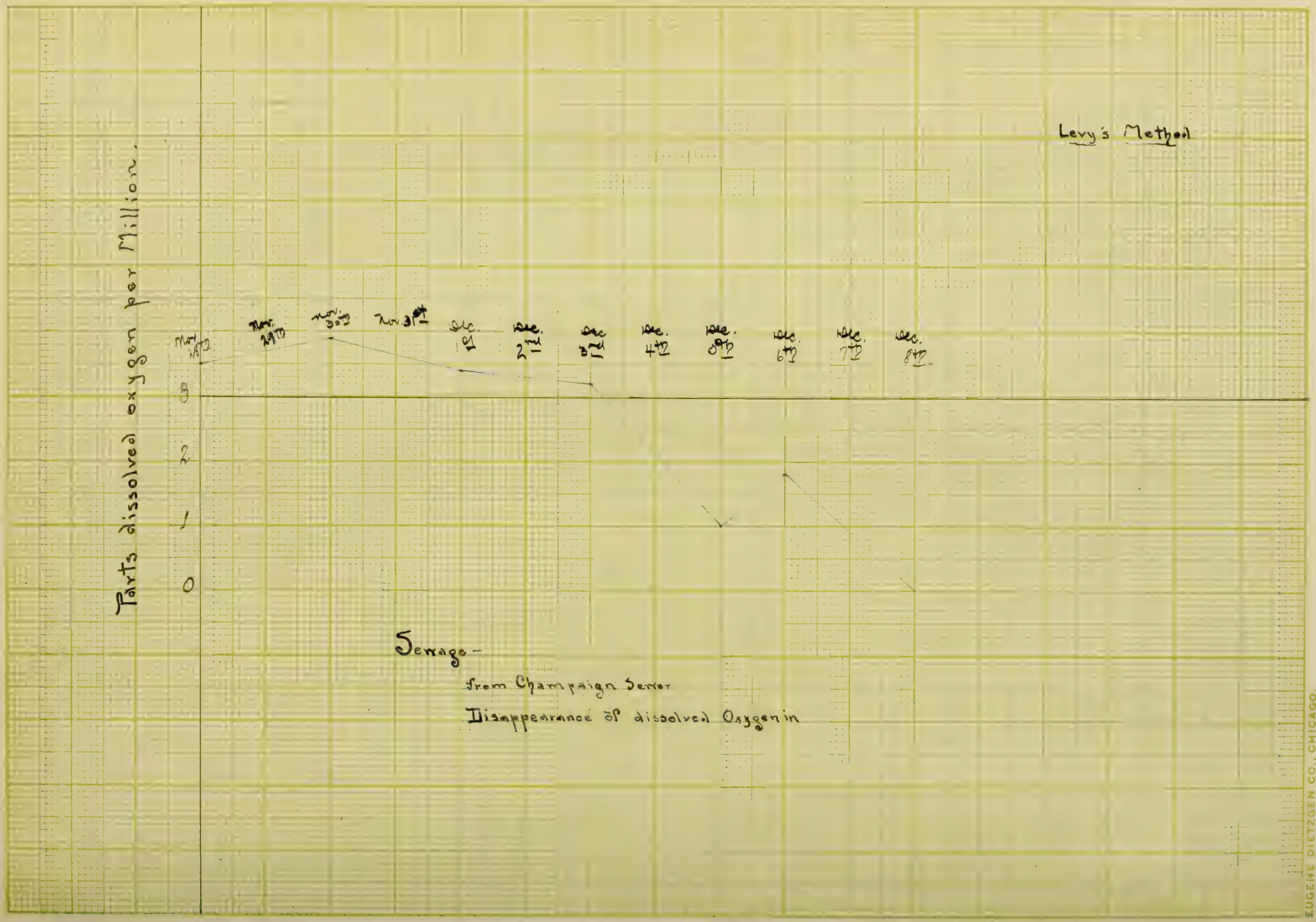
At 2 30 P.M. it was tested. The dissolved oxygen was then given in the nitrometer, the degree of aeration having been as

three 300 c.c. bottles were filled with the sewage by means of the suction syringe using the a Low precautions not to agitate or cause displacement of first water entering the bottles.

These bottles were placed in a cool dark place in my desk and were left to stand 24, 48, 60, 72 hrs, hours before determining if any increase or decrease in aeration had taken place.

Sewage by the Levy Method.

Date of Collection of Sample	Date and hour of Examination	Temperature when Collected	Parts dissolved Oxygen per Million	Percentage Saturation	N. as Nitrites	N. as Free Ammonia
Nov. 28th.	Nov 28th.	14°C	3.5	34.2	- -	- -
	3 00 P.M.		3.5			
" "	Nov. 30th.	"	3.9	37.79	.....	------
	10 00 A.M.		4.0			
" "	Dec. 1st.	"	3.4	33.21	----	----
	10 50 A.M.		3.3	32.31		
" "	Dec. 3rd.	"	3.2	31.41	3.0	25.0
	8 25 A.M.		3.1	30.52		
" "	Dec. 5th.	"	1.0	9.65	2.0	25.0
	10 30 A.M.		1.0			


Levy's Method
Parts dissolved oxygen per Million.
Nov. 29th
Nov. 30th
Dec. 1st
Dec. 2nd
Dec. 3rd
Dec. 4th
Dec. 5th
Dec. 6th
Dec. 7th
Dec. 8th
Sewage –
from Champaign Sewer
Disappearance of dissolved Oxygen in

Date of Collection	Date and hour of Examination	Temperature when Collected	Parts dissolved Oxygen per Million	Percentage Saturation	N. as Nitrites	N as Free Ammonia
Nov. 28th.	Dec. 6th.	14°C	1.9	18.33	3.0	30.0
	10^00 A.M.		1.9			
" "	Dec. 7th.	"	0.0	0.0	2.0	20.0
	9^30 A.M.		0.0	0.0		
" "	Dec. 10th.	"	0.0	0.0	2.0	20.0
	9^00 A.M.		0.0			

On 3rd inst. [illegible] obtained two more bails of sewage from above and [illegible] Laboratory, [illegible] the sewage through chemical and determined the percentage saturation of the water and the amount of nitrate and free ammonia present.

Then the bottles were filled* with the sewage, stoppered, and set in a dark place.

I now took about a gallon of the sewage used in a large [illegible] and shook vigorously for five minutes, and aerated the oxygen in the bottle by passing into it a current of [illegible] air. The two [illegible] sewage was repeatedly shaken up with [illegible] and [illegible] passed into the bottle [illegible] Lastly the amount of oxygen absorbed by the [illegible] determined and a [illegible]

well filled tube at [illegible] of each [illegible] and titrated at once [illegible] hours.

* In all estimations these were made in duplicate. That is, if one was done with the sample exposed to the atmosphere, the second flask was filled and immediately closed and treated in the same manner.

Normal Sewage

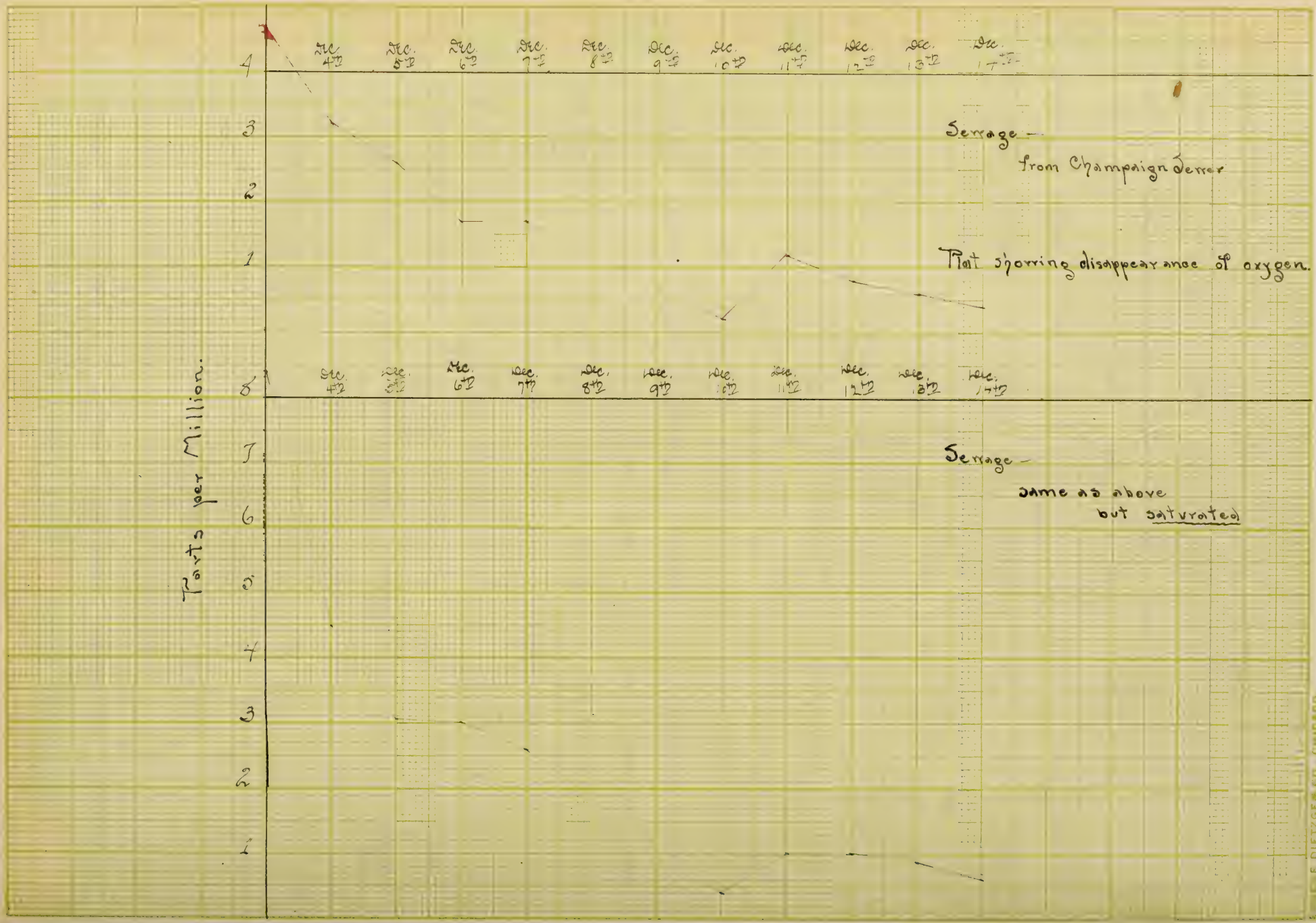
Date of Collection	Date and Hour of Examination	Temperature when Collected	Parts. diss. Oxygen per Million	Percentage Saturation	N. as Nitrites	N. as Free Ammonia
Dec. 3rd	Dec 3rd.	14°C	4.74	45.76	3.5	20.0
	3 P.M		4.74			
" "	Dec. 4th.	"	3.25	31.37	7.0	15.0
	9 30 A.M.		3.25			
" "	Dec. 5th.	"	2.6	25.09	3.0	30.0
	10 A.M.		2.6			
" "	Dec. 6th.	"	1.67	16.11	3.0	40.0
	10 30 A.M.		1.89	18.24		
" "	Dec. 7th.	"	1.78	17.18	2.0	15.0
	10 A.M.		1.78			
" "	Dec. 10th.	"	0.22	2.15	2.0	36.0
	10 40 A.M.		0.22			
" "	Dec. 11th.	"	1.18	10.8	0.015	40.0
	9 30 A.M.		1.18			

Sewage, normal, continued

Date of Collection	Date and hour of Examination	Temperature when Collected	Parts dissolved oxygen per Million	Percentage Saturation	N. as Nitrites	Nitrogen as Free Ammonia
Dec. 3rd	Dec. 12th.	14°C	0.89	8.63	0.015-	60.0
	8 40 A.M.		0.89			
" "	Dec. 13th.	"	0.67	6.47	0.025-	40.0
	9 30 AM		0.67			
" "	Dec. 14th.	"	0.49	4.74	0.025-	15.0
	10 30 A.M.		0.49			

Sewage partly saturated with air

Dec. 3rd	Dec. 3rd	14°C	8.46	81.66	3.5-	20.0
	5 00 P.M.		8.46			
" "	Dec. 4th.	"	4.46	43.05-	6.0	15.0
	8 30 AM.		4.46			
" "	Dec. 5th.	"	3.10	29.92	6.0	35.0
	9 30 AM.		3.10			
" "	Dec. 6th.	"	3.0	28.95-	4.0	40.0
	10 55 AM		3.0			
" "	Dec. 7th.	"	2.6	25.09	4.0	15.0
	10 30 A.M.		2.6			
" "	Dec. 10th.	"	0.44	4.31	3.0	41.0
	10 40 A.M.		0.44			
" "	Dec 11th.	"	1.18 1.18	1.08	3.0	40.0
	9 40 AM. 11 00 AM.		1.18 1.18			
" "	Dec. 12th. 9 20 AM.	"	1.18 1.18	1.08	2.0	40.0
" "	Dec. 13th. 9 30 AM.	"	0.89 0.89	0.86	1.5-	40.0
" "	Dec. 14th.	10 30 A.M.	"	0.688 0.786	0.65- 0.75-	1.0	15.b


Dec. 4th
Dec. 5th
Dec. 6th
Dec. 7th
Dec. 8th
Dec. 9th
Dec. 10th
Dec. 11th
Dec. 12th
Dec. 13th
Dec. 17th
4
3
2
1
0
Sewage —
from Champaign Sewer
Plot showing disappearance of oxygen.
Parts per Million.
Dec. 4th
Dec. 5th
Dec. 6th
Dec. 7th
Dec. 8th
Dec. 9th
Dec. 10th
Dec. 11th
Dec. 12th
Dec. 13th
Dec. 17th
7
6
5
4
3
2
1
Sewage —
same as above
but saturated

The first of the two [illegible] by the [illegible] was to show that sewage waters [illegible] nitrites and that after standing for nine days the dissolved oxygen in the water had entirely disappeared. By a comparison of the [illegible] with the tests of the same sample of water saturated and normal, we see that in [illegible] there is a constant decrease in the amount of saturation; the average [illegible] of a number of the solutions with a decrease in the [illegible] nitrites. She was also able to [illegible] some idea of what the amount of oxygen remaining in the saturated and normal samples was almost the same, showing that there [illegible] air, in which the organic matter had [illegible] the oxidation.

Following Miss, some experiments were made upon the deoxygenation of aerated oxygen in the Illinois River water.

Monday, December 24th, [illegible] bottles were filled from the Illinois, between the hours of 11 and 11 A. M. The water was taken from the channel, between the second and third locks at the Feeder Dam bridge at Kenwood. It had been used in the [illegible], and the water was dirty [illegible] of a long rather [illegible] and [illegible]

about fourteen inches below the surface of the water and connected with the pumping engines.

The temperature of the water was 1°C and after collection it was immediately taken to the Sanitary District pumping station and tested. The tests were then tested at regular intervals. The following result. Two seven gallon bottles were filled with water taken from the channel of the Illinois River, six miles below the city about fifty yards above the entrance into the river, on the south side of the East Bridge.

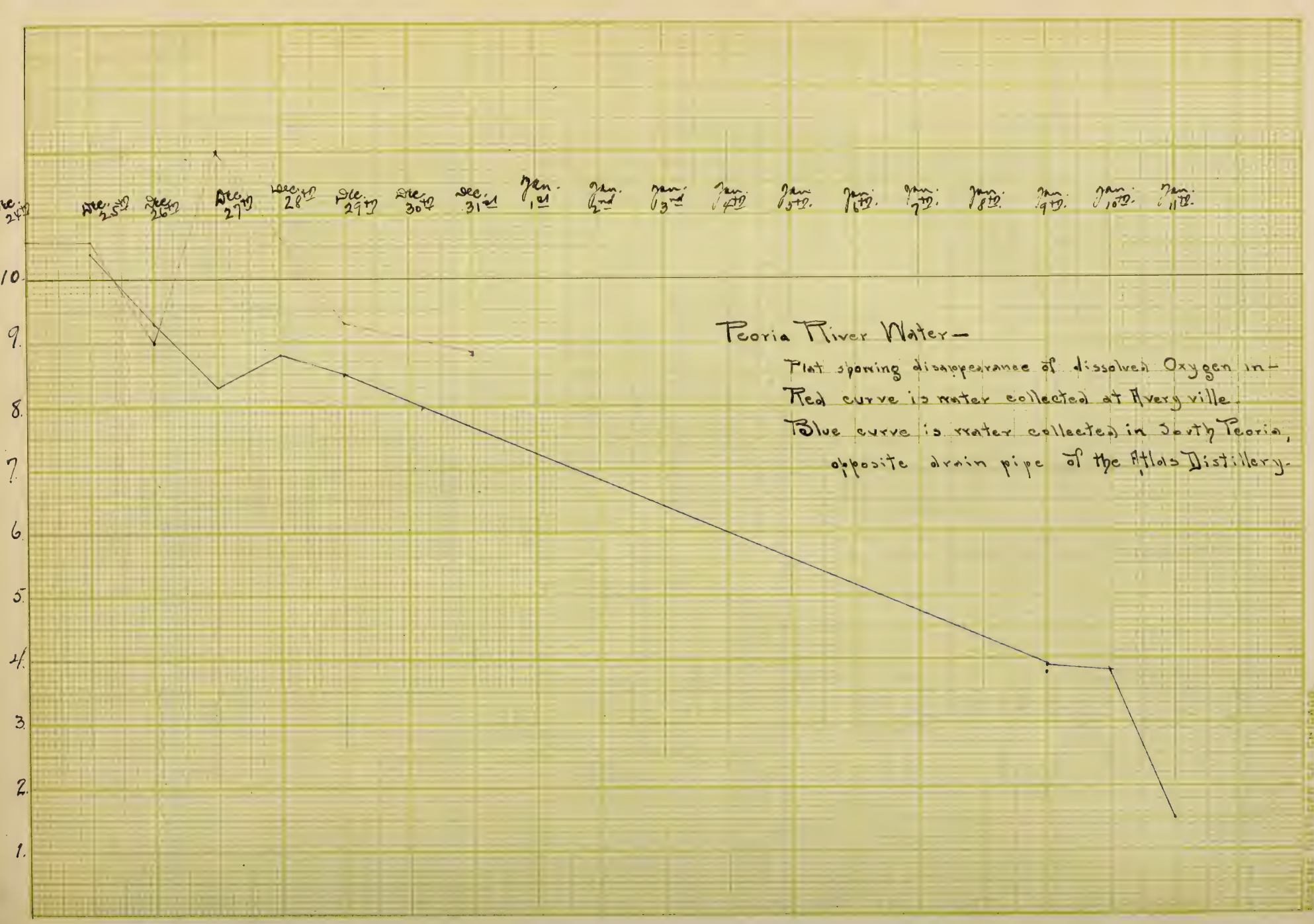
This collection was made between 3 and 4 o'clock in the afternoon and it took us about an hour to reach the pumping station. But the engineer made a determination of this collection immediately in the water above until the next day before it was handed to experiment upon. The tabulated results of these tests were given.

Illinois River Water at Averyville

Date of Collection of Sample	Date and hour of Examination	Temperature when Collected	Parts dissolved Oxygen per Million	Percentage Saturation	Nitrogen as Nitrites	Free Ammonia
December 24th	Dec. 24th.	1°C	10.6	74.28	0.008	4.0
	11:30 A.M.		10.5	73.58		
" "	Dec. 25th.	"	10.6	74.28	0.008	4.0
	12:00 A.M.		10.5	73.58		
" "	Dec. 26th.	"	9.04	63.34	0.03	5.0
	10:30 A.M.		9.04			

Averyville water continued.

Date of Collection of Sample	Date and hour of Examination	Temperature when Collected	Parts dissolved oxygen per Million	Percentage Saturation	N. as Nitrites	N. as Free Ammonia
Dec. 24th.	Dec. 27th.	1°C	11.02	72.22	0.06	4.0
	10³⁰ A.M.		11.02			
	12⁰⁰ A.M.		11.02			
			11.71	75.05		
" "	Dec. 28th.	"	10.7	75.05	0.08	2.0
	10⁴⁵ A.M.		10.4	72.88		
" "	Dec. 29th.	"	9.3	65.17	0.04	4.0
	10⁴⁵ A.M.		9.3			
" "	Dec. 31st.	"	8.84	61.91	0.04	0.2
	10³⁰ A.M.		8.84			
	Illinois River Water at South Peoria.					
Dec 24th.	Dec. 24th.	1°C	----	----	----	----
Dec. 24th.	Dec. 25th.	"	10.44	72.88	0.016	6.0
	11 A.M.		10.44			
" "	Dec. 26th.	"	9.4	65.87	0.02	4.0
	11⁰⁰ A.M.		9.4			
" "	Dec. 27th.	"	8.2	57.46	0.065	5.0
	11³⁰ A.M.		8.3	57.16		
" "	Dec. 28th.	"	8.8	61.94	0.065	1.0
	11⁰⁰ A.M.		8.8			
" "	Dec. 29th.	"	8.6	60.27	0.075	4.0
	11¹⁵ A.M.		8.5	59.57		
" "	Dec. 31st.	"	7.7	54.66	0.3	2.0
	11¹⁵ A.M.		7.6	53.95		


Dec. 24th
Dec. 25th
Dec. 26th
Dec. 27th
Dec. 28th
Dec. 29th
Dec. 30th
Dec. 31st
Jan. 1st
Jan. 2nd
Jan. 3rd
Jan. 4th
Jan. 5th.
Jan. 6th.
Jan. 7th.
Jan. 8th.
Jan. 9th.
Jan. 10th.
Jan. 11th.
10.
9.
8.
7.
6.
5.
4.
3.
2.
1.
Peoria River Water—
Flat showing disappearance of dissolved Oxygen in—
Red curve is water collected at Averyville.
Blue curve is water collected in South Peoria,
opposite drain pipe of the Atlas Distillery.

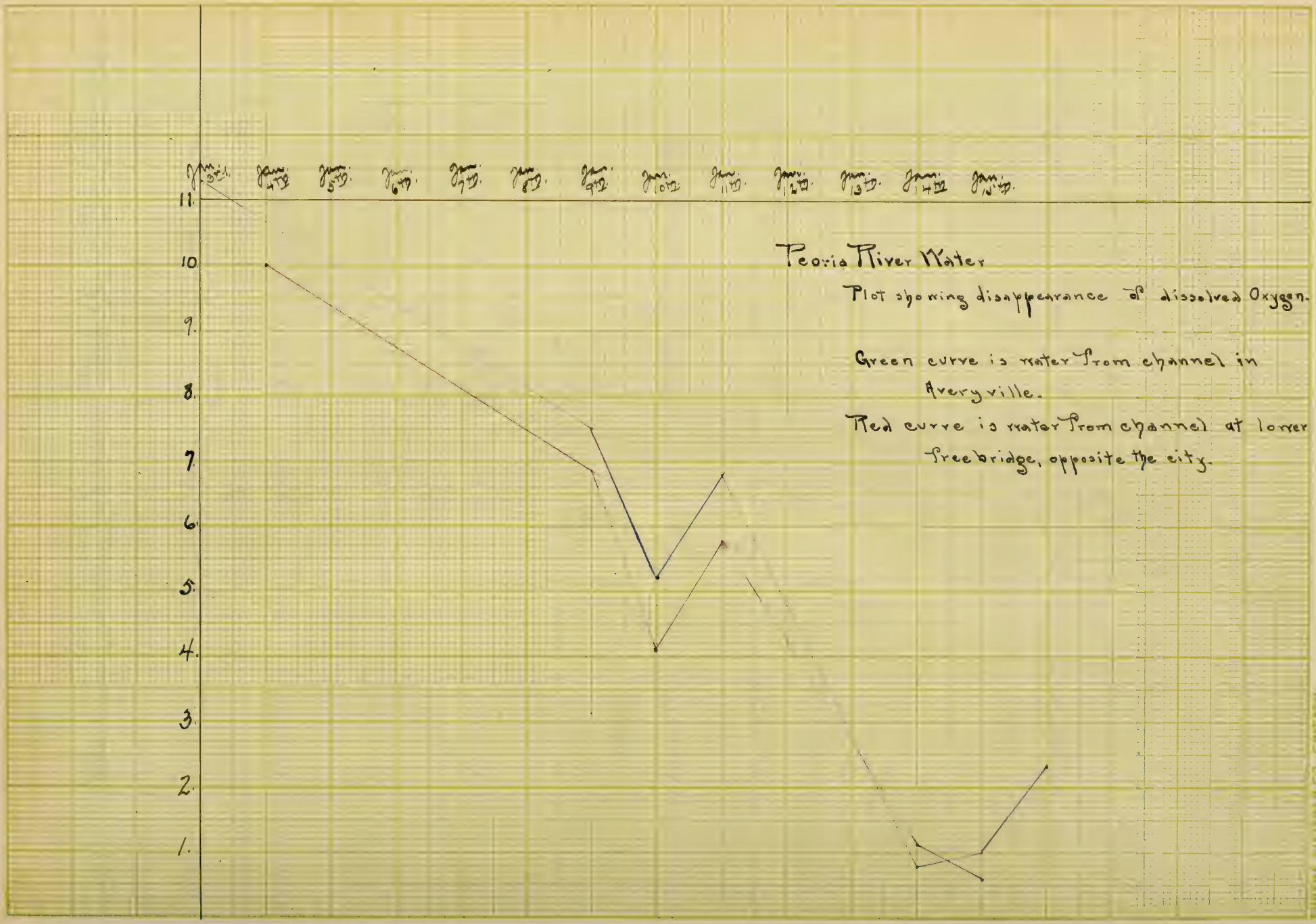
South Peoria water continued

Date of Collection of Sample	Date and hour of Examination	Temperature when Collected	Parts dissolved oxygen per Million	Percentage Saturation	N. as Nitrites	N. as Free Ammonia
Dec. 24th.	Jan. 9th.	1°C	3.9	27.4	0.05-	2.0
	10:20 AM.		3.9			
" "	Jan. 10th.	"	3.8	26.62	0.05	2.0
	10:35 AM.		3.8			
" "	Jan. 11th.	"	1.5-	10.51	0.01	3.0
	9:0 AM.		1.5-			

On the 3rd of Jan. the water in the bottles each was collected from the river at the foot of the channel at Averyville and the other from the channel between the second and third piers of the lower iron bridge, about the city of Peoria

Illinois River Water at Averyville

Date of Collection	Date and hour of Examination	Temperature when Collected	Parts dissolved oxygen per Million	Percentage Saturation	Nitrites	Free NH_3
January 3rd	Jan. 3rd	1°C	11.3	79.18	0.008	4.0
	10:30 A.M.		11.3			
" "	Jan. 9th.	"	7.66	5-3.67	0.35-	5.0
	10:5 AM.		7.47	5-2.34		
" "	Jan. 10th.	"	7.27	5-1.04	0.05-	3.0
	4:0 AM.		7.27			
" "	Jan. 11th.	"	7.0	49.05-	0.125-	5.0
	9:0 A.M.		7.0			
" "	Jan 14th.	"	0.8	6.16	0.2	2.0
	8:55 AM.		0.8			
" "	Jan. 15th	"	1.0	7.0	0.2	4.0
	7:0 AM.		1.0			
" "	Jan. 16th.	"	2.3	16.11	0.15-	4.0
	8:0 AM.		2.3			



Peoria River Water

Plot showing disappearance of dissolved Oxygen.

Green curve is water from channel in Averyville.

Red curve is water from channel at lower Freebridge, opposite the city.

Illinois River Water collected from lower bridge

Date of Collection of Sample.	Date and Hour of Examination	Temperature when Collected	Part s dissolved Oxygen	Percentage Saturation	Nitrogen as Nitrites	Nitrogen as Free Ammonia
January 4th.	Jan. 4th.	3° C	10.0	88.41	0.004	1.2
	11^00 A.M.		10.0			
" "	Jan. 9th.	"	6.9	61.0	0.075	3.0
	11^55 A.M.		6.9			
" "	Jan. 10th.	"	4.12	37.31	0.4	1.0
	3^40 P.M.		4.12			
" "	Jan. 11th.	"	5.79	51.79	0.15	1.0
	10^10 A.M.		5.79			
" "	Jan. 14th.	"	1.1	9.72	0.3	2.0
	9^40 A.M.		1.1			
" "	Jan. 15th.	"	0.6	5.3	0.2	3.0
	9^40 A.M.		0.6			

A glance at the last column of dissolved oxygen will show that the water when it received the silt to settle was rather highly saturated, and after standing for twelve hours did not decrease its amount of dissolved oxygen and that

[illegible] sudden as the water obtained [illegible] city. The results show that as far as organic matter is concerned, the water from [illegible] city conforms does not [illegible] that entering the city's mains. The two series run from water collected at Averyville and [illegible] the city. Ozone also strengthens the [illegible]

The Averyville water is more highly saturated but for this loses the decrease of bacteria. The two water samples parallel, that the water collected at the [illegible] Lake a number and. From this point [illegible] it is clear to see that the water below it receives the city's [illegible] pure condition than it is after it leaves it.

Ammonia titrations were also made on the water to see if the conclusions of the air which [illegible] the water which [illegible]

Date of Collection of Sample	Date and hour of Examination.	Temperature when Collected	Parts dissolved Oxygen per Million	Nitrites	Free NH3	Percentage Saturation
"Averyville Water"						
December 24th	Dec. 24th.	1° C	10.6	0.008	4.0	74.28
	11:30 A.M.		10.5		4.0	
January 3rd	Jan. 3rd.	"	11.3	0.008		79.18
	12:10 A.M.		11.2		4.0	
December 29th.	Dec. 29th.	"	11.8	0.008		88.14
	12:10 A.M.		11.9			
"Lower Bridge" water	Jan. 4th.	"	10.0	0.004	1.2	74.07
January 4th	11:00 A.M.		10.0			

7

The above bacteria were fed the acids, were above and after the city was fairly well saturated. A new sample to determine the dissolved oxygen content

At 9 A.M. Feb 8th a collection was made from the manhole on the University campus and saturated at once with air in the same manner as the sample for electrolysis. After vigorous shaking for ten minutes, saturation and more than enough to fill the bottle. Immediately to be tested. Saturation and more than enough to fill the bottle. The bottle was then filled with the sewage. To series No 2 was added 0.2 g of potassium chlorate and to series No 3 added one large dro of Chloroform. The bottles were then carefully stoppered and set aside in a cool dark place.

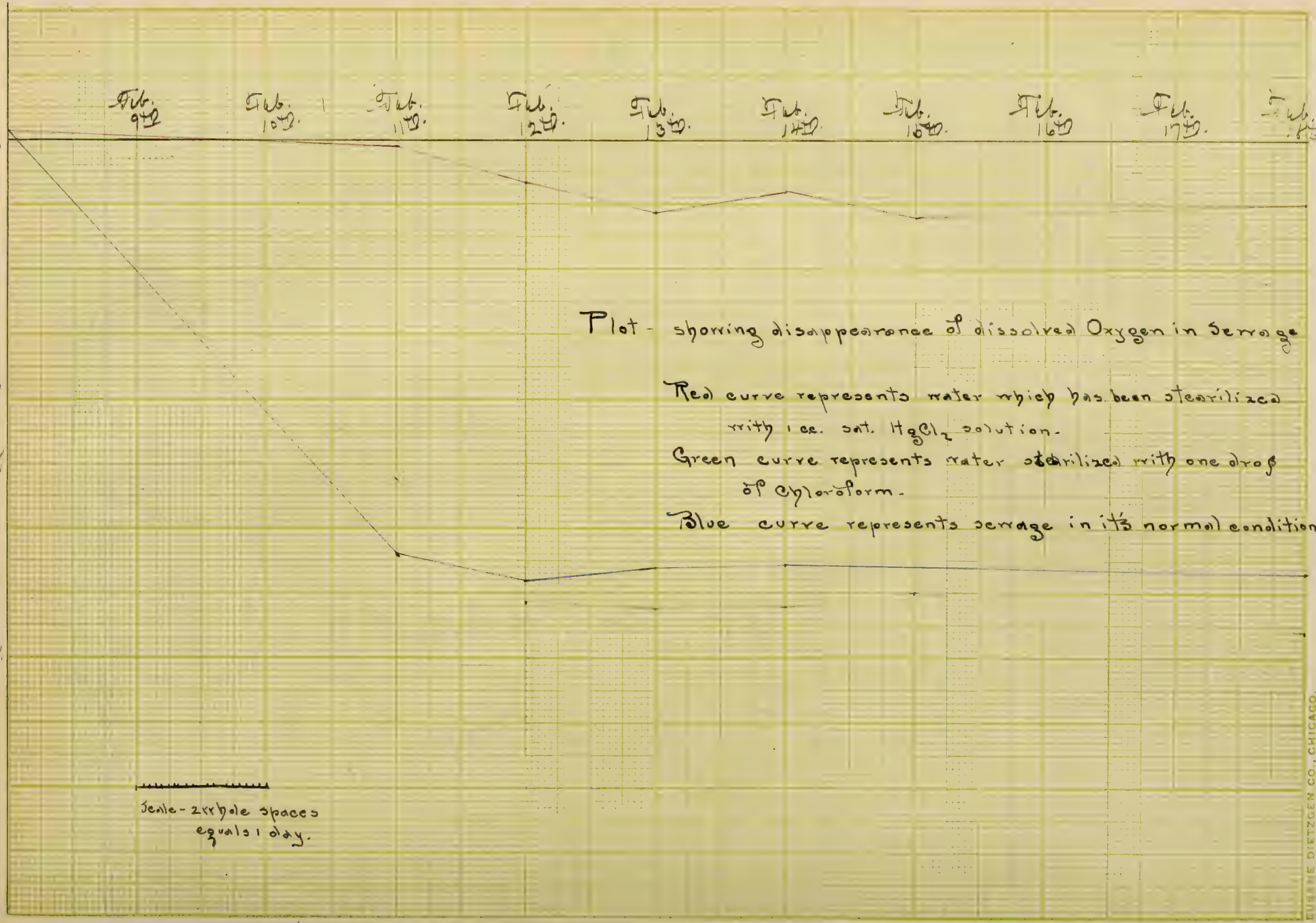
The results follow.

Sewage normal, saturated

Date of collection of Sample	Date and hour of Examination	Temperature when Collected	Parts dissolved Oxygen per Million	Percentage Saturation
Feburary 8th.	Feb. 8th.	7°C	9.13	75.02
	10:20 A.M.		9.13	
" "	Feb. 11th.	"	2.6	21.36
	2:00 P.M.		2.6	
" "	Feb. 12th. 1:45 P.M.	"	2.2.	18.07

Normal saturated Sewage Continued

Date of Collection of Sample	Date and hour of Examination	Temperature when Collected	Parts dissolved Oxygen per Million	Percentage Saturation
Feburary. 8th.	Feb. 13th.	7° C.	2.49	20.53
	1.45 P.M.		2.49	
" "	Feb. 14th.	"	2.4	19.72
	3.00 P.M		2.34	18.88
" "	Feb. 15th.	"	2.4	19.72
	1.45 P.M.		2.5	21.17
" "	Feb. 18th.	"	2.3	18.88
	1.45 P.M.		2.3	
	Sewage same as above plus mercurie chloride			
Feburary. 8th.	Feburary 8th.	7° C	9.13	75.02
	10.20 A.M.		9.13	
" "	Feb. 11th.	"	8.9	73.13
	2.30 P.M.		8.9	
" "	Feb. 12th.	"	8.4	69.02
	2.30 P.M.		8.2	67.37
" "	Feb. 13th.	"	7.9	65.45
	2.05 P.M.		7.8	64.8
" "	Feb. 14th.	"	8.2	67.37
	2.35 P.M.		8.2	
" "	Feb 15th.	"	7.81	64.17
	2.35 P.M.		7.81	
" "	Feb. 18th.	"	7.9	65.45
	2.35 P.M.		7.8	65.17


Feb. 9th
Feb. 10th.
Feb. 11th.
Feb. 12th.
Feb. 13th.
Feb. 14th.
Feb. 15th.
Feb. 16th
Feb. 17th.
9.
8.
7.
6.
5
4.
3.
2.
1.
Plot - showing disappearance of dissolved Oxygen in Sewage
Red curve represents water which has been sterilized with 1 cc. sat. $HgCl_2$ solution.
Green curve represents water sterilized with one drop of Chloroform.
Blue curve represents sewage in its normal condition.
Scale - 2 whole spaces equals 1 day.
EUGENE DIETZGEN CO., CHICAGO.

Sewage same as above plus chloroform.

Date of Collection of Sample	Date and hour of Examination	Temperature when Collected	Parts dissolved Oxygen per million	Percentage Saturation
February 8th.	Feb. 8th.	7°C	9.13	75.02
	10^00 A.M.		9.13	
" "	Feb. 11th.	"	3.65	29.9
	3^20 P.M.		3.65	
" "	Feb. 12th.	"	1.9	15.62
	2^45 P.M.		1.9	
" "	Feb. 13th.	"	1.79	14.7
	2^45 P.M.		1.79	
" "	Feb. 14th.	"	1.8	14.79
	3^00 P.M.		1.8	
" "	Feb. 15th.	"	2.02	15.69
	3^00 P.M.		2.02	
" "	Feb. 18th		1.2	13.96
	3^00 P.M.		1.7	

Another collection of sewage was made from the University Manhole and three series of 10 bottles each were made using mercuric chloride, chloroform and normal sewage as per above.

The tabulated results follow

Sewage normal, saturated.

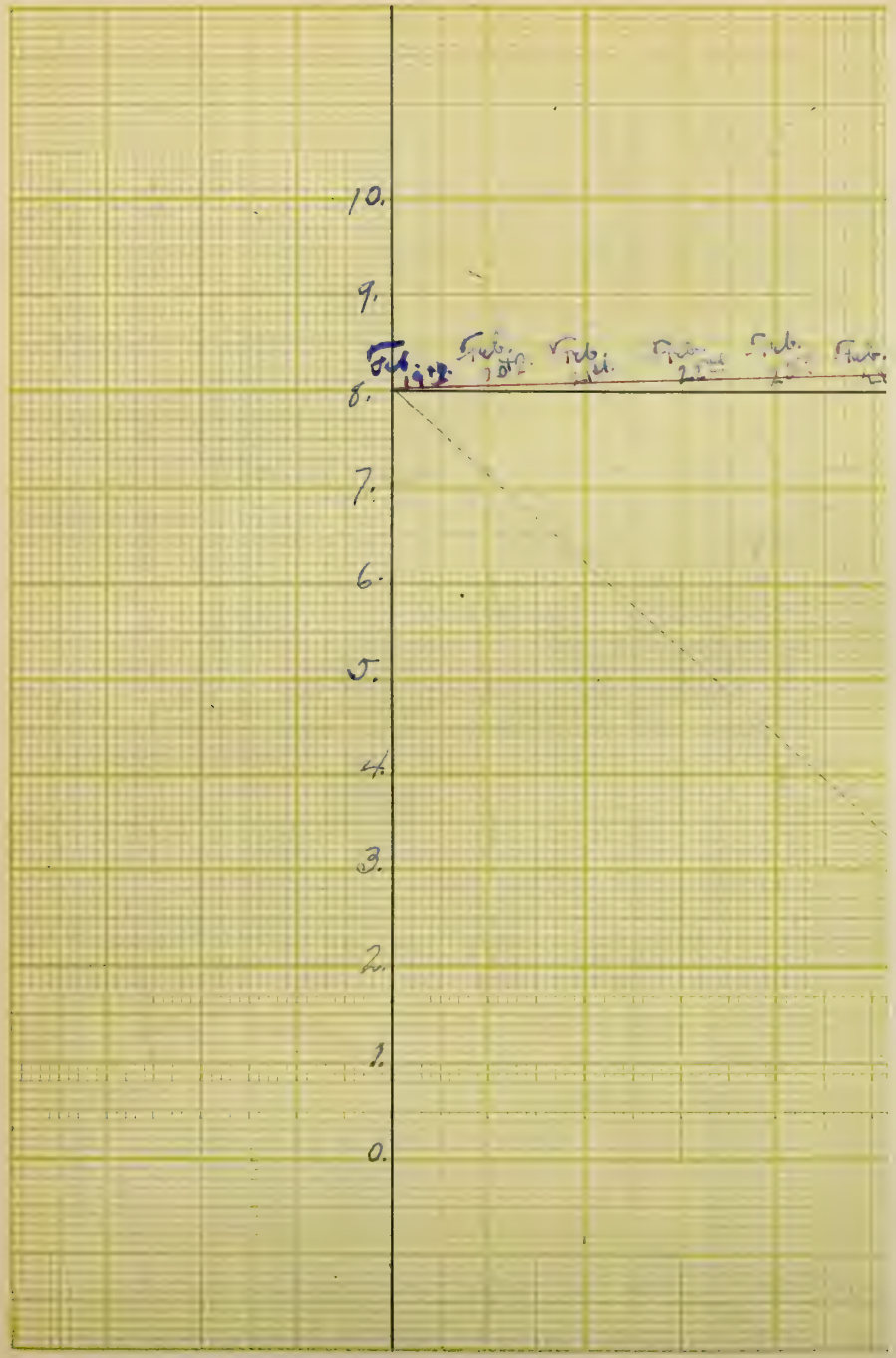
Date of Collection of Sample	Date and hour of Examination	Temperature when collected	Parts dissolved Oxygen per. Million	Percentage Saturation
February 19th. 01	Feb. 19th.	2°C	7.88	56.81
	2 35 P.M.		7.88	
" "	Feb. 25th.	"	2.5	18.02
	1 45 P.M.		2.5	
" "	Feb. 26th.	"	2.34	16.87
	2 15 P.M.		2.5	18.02
" "	March 1st	"	1.93	13.91
	2 05 P.M.		1.93	
" "	March. 4th.	"	2.6	19.03
	1 45 P.M.		2.6	
" "	March. 6th.	"	2.13	15.41
	2 10 P.M.		2.13	
" "	March. 8th.	"	0.81	5.8
	2 00 P.M.		0.81	
" "	March. 12th.	"	0.91	6.61
	2 30 P.M.		0.91	
" "	March. 15th.	"	0.81	5.8
	2 10 P.M.		0.81	
" "	March. 18th.	"	1.01	7.98
	2 20 P.M.		1.01	

Series No 2- $HgCl_2$ added

Date of Collection of Sample	Date and hour of Examination	Temperature when Collected	Parts dissolved Oxygen per M.	Percentage Saturation
February 19th.	Feb. 19th. 3 45 P.M.	2°C	7.88 7.88	56.81
"	Feb. 25th. 2 30 P.M.	"	8.04 8.22	57.97 59.26
"	Feb. 26th. 2 45 P.M.	"	8.31 8.31	59.91
"	March. 1st. 2 50 P.M.	"	8.65 8.65	63.36
"	March. 4th. 2 10 P.M.	"	8.63 8.63	62.27
"	March. 6th 2 30 P.M.	"	9.87 9.87	71.19
"	March. 8th. 2 30 P.M.	"	9.16 9.16	66.05
"	March. 12th. 3 00 P.M.	"	9.87 9.87	71.19
"	March. 15th 2 40 P.M.	"	8.55 8.55	61.64
"	March. 18th. 2 45 P.M. (Sample + $(NH_4)_2S$ had been added)	"	8.04 8.04	57.04
"	March. 18th. 4 00 P.M.	"	3.25 3.25	23.46

Series No 3 – disinfected with $CHCl_3$

Date of Collection of Sample	Date and hour of Examination	Temperature when Collected	Parts dissolved Oxygen per Million.	Percentage Saturation.
February 19th	Feb. 19th.	2° C.	7.88	56.81
1901	3 45 P.M.		7.88	
"	Feb. 25th.	"	2.57	18.53
	3 15 P.M.		2.57	
"	Feb. 26th.	"	1.48	10.67
	3 20 P.M.		1.48	
"	March. 1st.	"	3.86	27.88
	2 50 P.M		3.86	
"	March. 4th.	"	3.05	22.09
	2 30 P.M.		3.05	
"	March. 6th.	"	2.85	20.54
	3 20 P.M.		2.85	
"	March. 8th.	"	2.64	19.08
	3 20 P.M.		2.64	
"	March. 12th.	"	2.13	15.41
	3 30 P.M.		2.13	
"	March. 15th	"	2.44	17.61
	3 45 P.M.		2.34	16.88
"	March. 18th.	"	2.13	
	3 20 P.M.		2.13	15.41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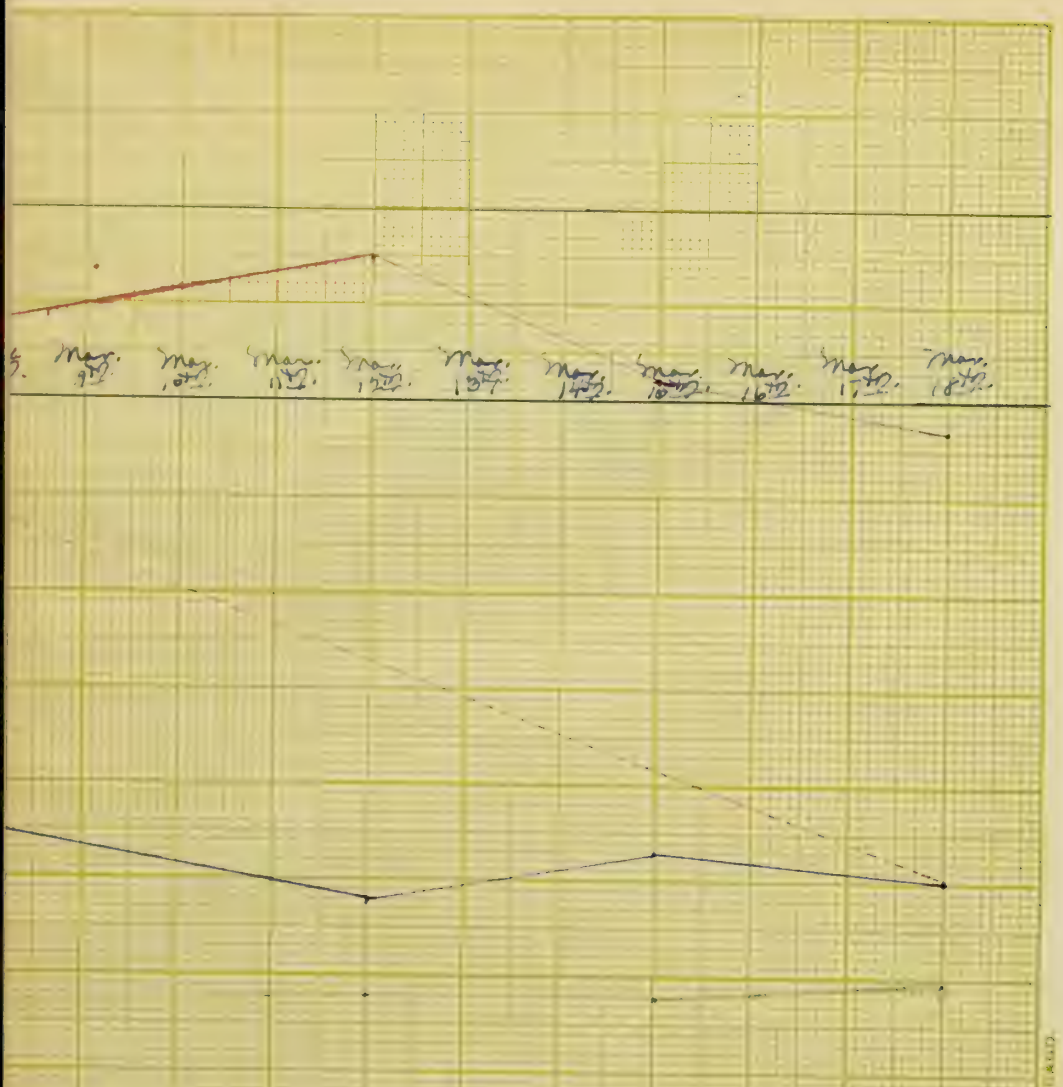
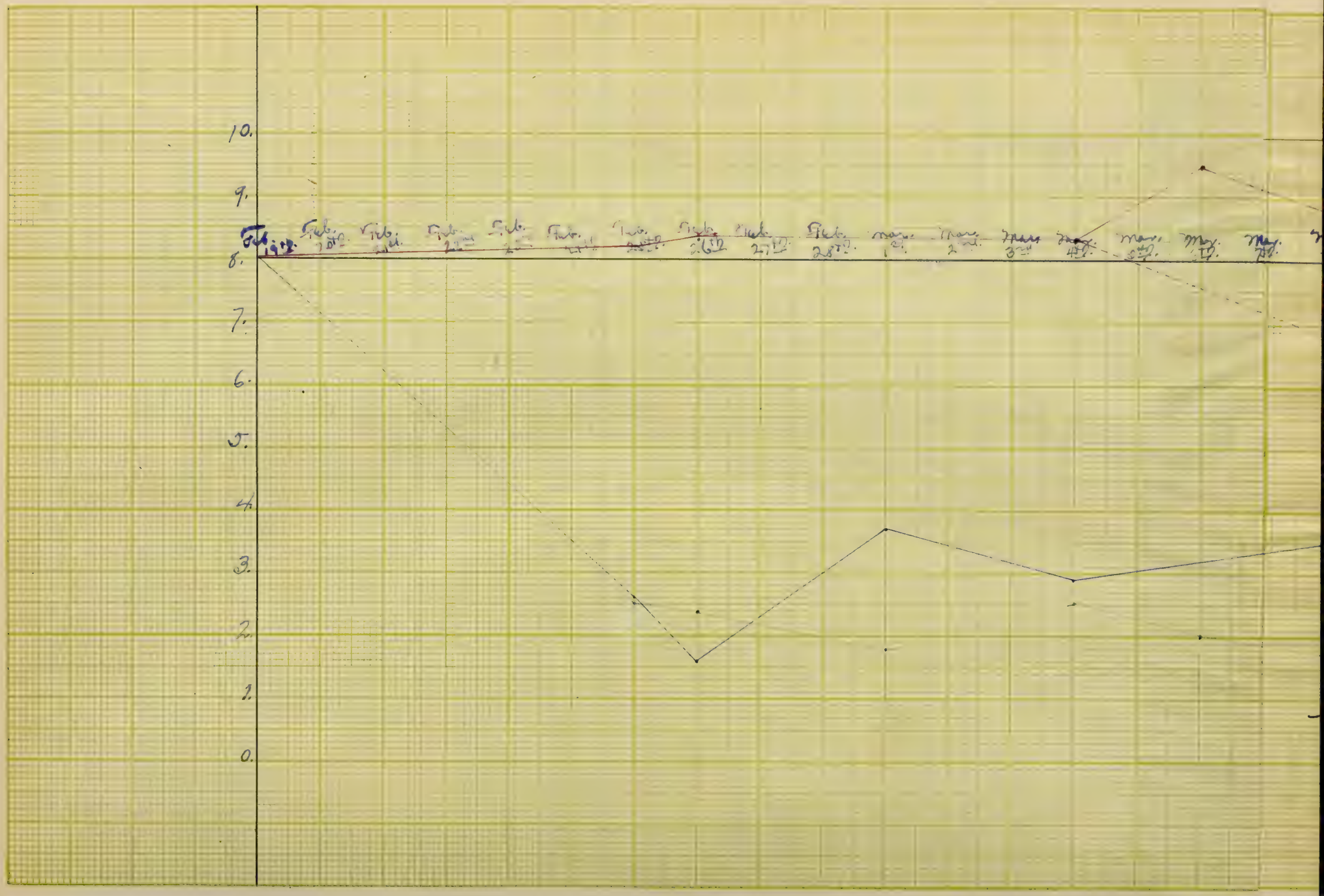


ot showing the disappearance of dissolved Oxygen in Champaign sewage
The red curve represents sewage sterilized with 1 cubic cent. of $HgCl_2$.
the dotted red curve is the sample to which $(NH_4)_2S$ was added.
The blue curve is sewage sterilized with chloroform.
The green curve is sewage in it's normal condition.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Under the ordinary conditions which we employ, the activity of the bacteria in sewage to which mercuric chloride in a dilution as far as chemical analysis is concerned, has not been added, remained above the normal for 24 hours and in the first case it took [illegible] per milligram to standing the days. Now adding mercuric chloride to the sewage a white cloudiness immediately ensued, which, after standing for several days, fell in the form of a white curdy precipitate. The fact is that $Hg Cl_2$ unites with the protoplasm of the bacteria in the sewage, producing a protochloride of mercury, just as we have formed the albuminate of mercury, in order to the white of an egg or other albumin containing substance. The formation, however, of this compound of protoplasm of bacteria and mercury, in each test to kill the bacteria but simply arrests their activity while in this form. If, moreover, we can, by any means, free us this compound it is further stated that the bacteria resume their former activity. To test this we [illegible] of Hydrogen [illegible] demand [illegible] it necessary to add to the [illegible]

with Hg_2 in order to oxidize it to form Hg and not leave any Hg_2 in the water. It was found that it required 0.05 of a c.c. of $\frac{1}{10}$ Hg_2 to inoculate the mercury with 1 c.c. of the Hg_2Cl_2 solution. This amount was added to the middle of the series in the tube, and the tube was then allowed to stand for 14 days. After several days standing the white Hg_2Cl_2 changed to the black Hg but even standing for 14 days and testing it was found that all the cases which had been sterilized with Hg_2Cl_2 and which did not have $(NHg)_2$ added contained 5.1 parts dissolved oxygen per million, the sample to which the $(NHg)_2$ had been added contained for 2.2 parts, and this seems to indicate that with the factors in the sample to which the $(NHg)_2$ had been added, removed their former activity and left the oxygen.

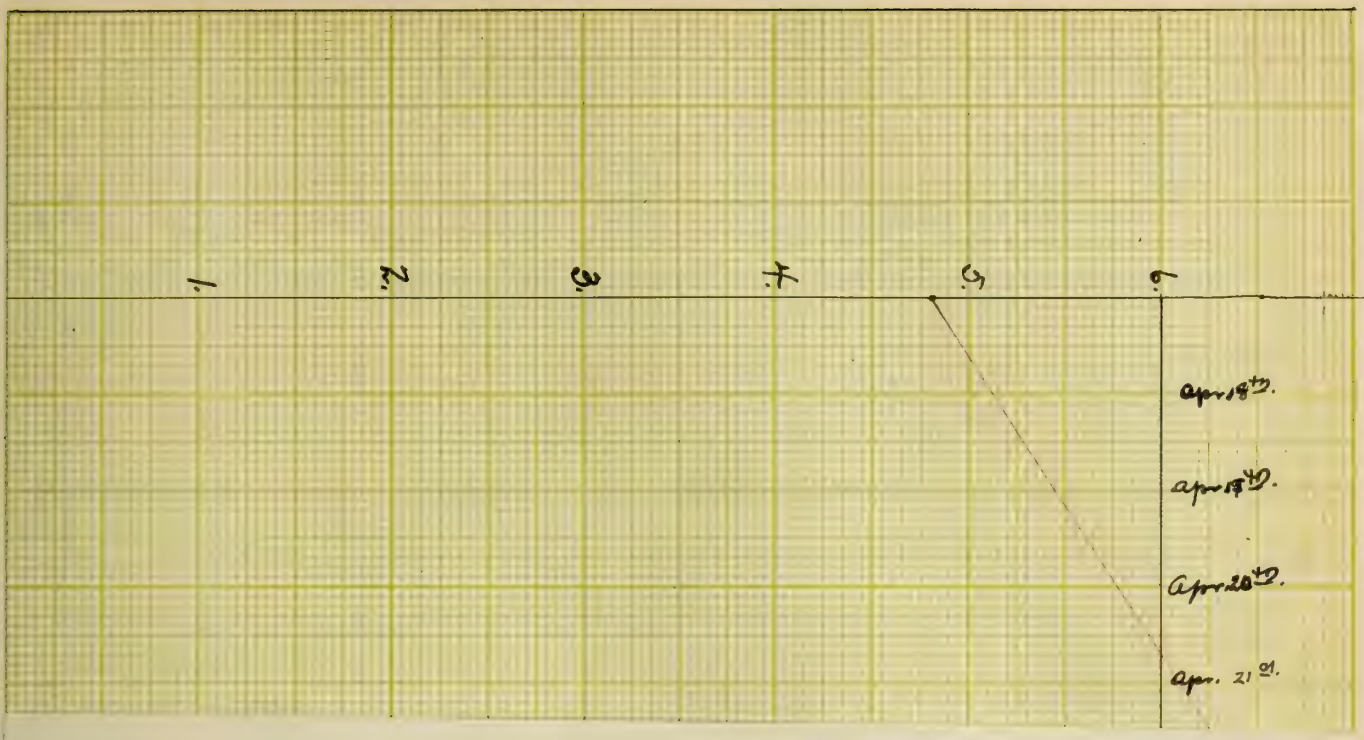
In order to test this fact more thoroughly I collected a number of samples in the field and filled a 2 gallon bottle with it. The temperature was 18°C. To this was added 25 c.c. of a saturated mercuric chloride solution. The bottle was then placed in the sun and allowed to remain there until it was opened on the 15th of April, and the

Percentage of saturation was subsequently determined. 200 c.c. titrated of the same $MnCl_2$ used above with a solution of N_{10} $N_{a_2}S_2O_3$ using as an indicator $Fe\ Cl_4$ on a porcelain dropping plate, no presence of free I_2 $N_{a_2}S_2O_3$ solution being required for the determination of $Mn(OH)_2$ but it would require 10.1 c.c. N_{10} $N_{a_2}S_2O_3$ to titrate the iodine liberated with the 25 c.c. of solution. This amount was carefully added to the mouth of the 2 bottles of control and the titre was obtained. Both bottles to mix and allowed to stand for two days. The precipitate had now all dissolved to flask form & now formed the titre, again determined the amount of aeration and titre formed by with the present standing to stand "relieved" titre, = 10.1 c.c. of the average and flask machine

Results:

Date of Collection of Sample	Date and hour of Examination	Temperature when Collected	Parts dissolved Oxygen per Million	Percentage Saturation
April. 3rd.	April. 3rd. 3.50 P.M.	15°C	6.55 6.55	61.84
(two days after adding $(NH_4)_2S$.)	April. 17th.	"	4.83	43.6
April. 17th.	3.40 P.M.		4.83	
" "	April. 23rd. 2.30 P.M.	"	6.75 6.75	63.78

Date of Collection of Sample	Date and hour of Examination	Temperature when Collected	Parts dissolved Oxygen per Million	Percentage Saturation
April. 17th.	April. 24th.	15°C	3.72	35.21
	2.45 P.M.		3.72	
" "	April. 25th.	"	5.04	47.59
	2.30 P.M.		5.04	
" "	April. 26th.	"	5.04	47.59
	9.20 A.M.		5.04	
" "	April. 28th.	"	4.63	43.78
	3.00 P.M.		4.63	
" "	April. 29th.	"	2.01	18.93
	3.40 P.M.		2.01	
" "	May. 2nd.	"	0.8	7.62
	3.20 P.M.		0.8	
" "	May. 7th.	"	1.31	12.18
	2.30 P.M.		1.31	
" "	May. 10th.	"	1.4	13.32
	3.20 P.M.		1.4	
" "	May. 13th.	"	0.9	8.56
	8.50 A.M.		0.9	
" "	May. 14th.	"	0.46	4.4
	3.40 P.M.		0.46	
" "	May. 15th.	"	0.93	8.8
	9.30 A.M.		0.93	
" "	May. 16th. 10.20 AM.	"	0.91	8.68
" "	May. 17th. 10.30 AM.	"	0.51	4.91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apr 18th.
apr 19th.
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apr. 21st.

Plot showing the disappearance of dissolved Oxygen in Sewage in which Mercuric Chloride was added first; then the Mercury was precipitated as the black HgS.

The analyses show that there is from twice to three times as much Cl_2 has been added with gold as oxygen uncombined, in quantity for the subsequent process, if pure water ammonium sulphide or nitrate be used. The presence of the mercury salts in after a certain depth, the uncertain but gradual diminution in the degree of aeration, and the only possible reason for the diminution is that the bacteria after a certain depth of time become more active, and a part of this may result in diminution of aeration rather than adding ammonium sulphide as suggested by the nitrification of mercury reacting into mercury and bacterial activity. This is a thing which I have not observed in nitrification (not)

An article in the Chemical News stating that bacteria may when the sulphuric acid in water, and that bacteria cannot live in a weak acid has all its sulphuric acid neutralized by the following experiment.

On the 9th of last, I collected a gallon of water from the ground in Cross Hill, Yorkshire was 5°C, determined its degree of aeration and then added enough chloride to make it acidify strongly. The added 5 c.c.

52

A magnesia mixture" (NH4Cl and NH4OH) is added to the solution of the phosphate and it is allowed to stand for 12 hours. The solution is filtered and the precipitate ammonium magnesium phosphate and ignited in the presence of air. This may be done in platinum or porcelain but if iron is present porcelain should be used. The ignition should be carried on at a dull red heat. Heavy platinum crucibles are attacked by the fusion mixture. It is heated from one to two hours.

* 11 grms. $Na_2HPO_4 + 2aq$ + 1 grm. NH_4Cl + 2 + 5 C.C. NH_4OH and make up to 250 c.c.

The calculation results are as follows.

Date of Collection of Sample.	Date and hour of Examination.	Temperature when Collected	Parts dissolved Oxygen per Million	Percentage Saturation.
April. 3rd	April. 3rd	15° C.	6.55	61.84
(Resaturated)	3.50 P.M.		6.55	
April. 17th.	April. 17th.	"	8.0	75.54
	2.40 P.M		8.0	
" "	April. 23rd.	"	4.23	39.97
	2.00 P.M		4.23	
" "	April. 24th.	"	4.93	46.64
	2.15 P.M.		4.93	
" "	April. 25th.	"	3.83	36.17
	1.45 P.M		3.83	
" "	April. 28th.	"	3.32	31.41
	2.40 P.M		3.32	
" "	April. 29th.	"	3.12	29.5
	3.00 P.M.		3.12	
" "	May. 2nd.	"	3.12	29.5
	3.00 P.M		3.12	
" "	May. 7th.	"	3.93	37.12
	2.30 P.M.		3.93	
" "	May. 9th.	"	3.72	35.26
	1.40 P.M.		3.72	
" "	May. 10th.	"	3.72	35.26
	2.20 P.M.		3.72	
" "	May. 13th.		2.8	26.51
	8.50 A.M.		2.8	

Plot showing the disappearance of dissolved oxygen in Sewage.

The black curve is sewage in which the phosphoric acid has been precipitated.

The red curve is sewage in its normal condition.

EUGENE DIETZGEN CO., CHICAGO.

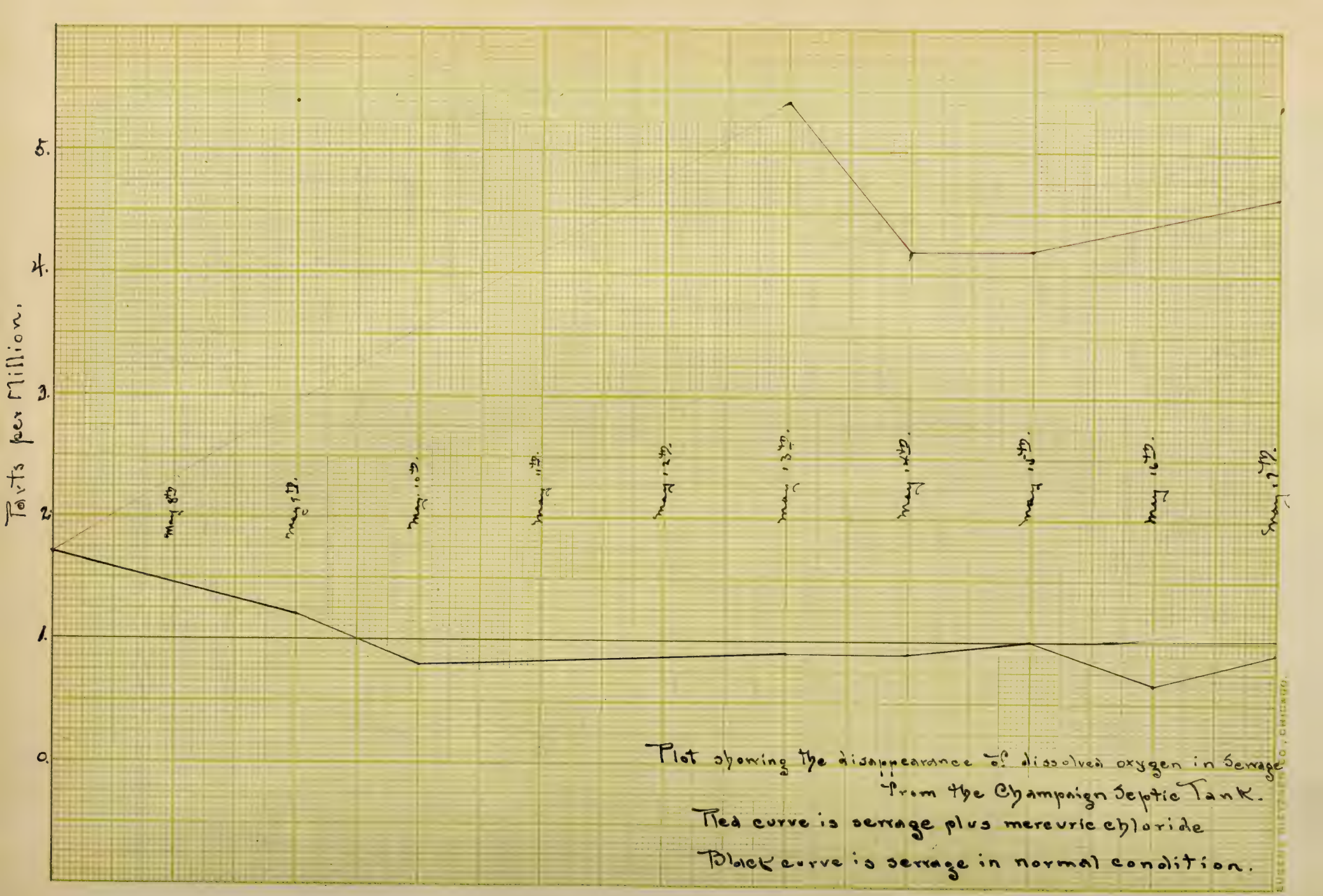
In testing the bulb and its tube for the disappearance of dissolved oxygen and nitrate nitrogen, it was found advisable to use two bulbs each of which contained two tubes, the former containing at the end of seven days over one half its tube contents and the latter at the end of a month also containing over a third of its contents. Two tubes in each bulb were filled for their growth and development, and both of the tubes could contain ammonia while nitrite could be detected only in the latter, as life means a consumption of nitrogen, and the nitrogen has disappeared.

The rest of my work is summarized also, was collected the 16th inst., from Lawrence Septic tank in Lawrence, Kan. Temp. 72° C. diluted at 2.5 P.M. and tubed with a pipette just before it began over the tank which carried the heavy matter from the tank.

It was taken to the laboratory, the dissolved oxygen determined and the series of dilution tubes set were made, the containing sewage in normal strength, and the tubes containing sewage standard with 1 c.c. $H_2 S_2$.

I do wonder if these two series are so [illegible]

Date of collection of Sample	Date and hour of examination	Temperature when collected	Parts dissolved Oxygen per Million	Percentage Saturation
May. 7th. '01	May. 7th	16° C	1.71	17.24
	5^00 P.M		1.71	
" "	May. 9th.	"	1.20	12.16
	1^40 P.M.		1.20	
" "	May. 10th.	"	0.8	8.12
	3^30 P.M.		0.8	
" "	May. 13th.	"	0.9	9.38
	1^40 P.M.		0.9	
" "	May. 14th.	"	0.9	9.38
	2^00 P.M.		0.9	
" "	May. 15th.	"	1.02	10.31
	8^50 A.M.		1.02	
" "	May. 16th.	"	0.65	6.58
	9^20 A.M.		0.65	
" "	May 17th.	"	0.91	9.15
	9^30 A.M.		0.91	
Sewage same as above, plus 1 c.c. $HgCl_2$ per. 300 c.c. Sewage.				
" "	May. 7th.	16° C	1.71	17.24
	5^00 P.M.		1.71	
" "	May. 13th.	"	4.4	43.26
	2^30 P.M.		4.4	
" "	May. 14th.	"	3.17	31.90
	3^15 P.M.		3.17	
" "	May. 15th.	"	3.17	31.90
	9^50 A.M.		3.17	
" "	May 17th.	"	3.64	36.47



Plot showing the disappearance of dissolved oxygen in Sewage from the Champaign Septic Tank.

Red curve is sewage plus mercuric chloride

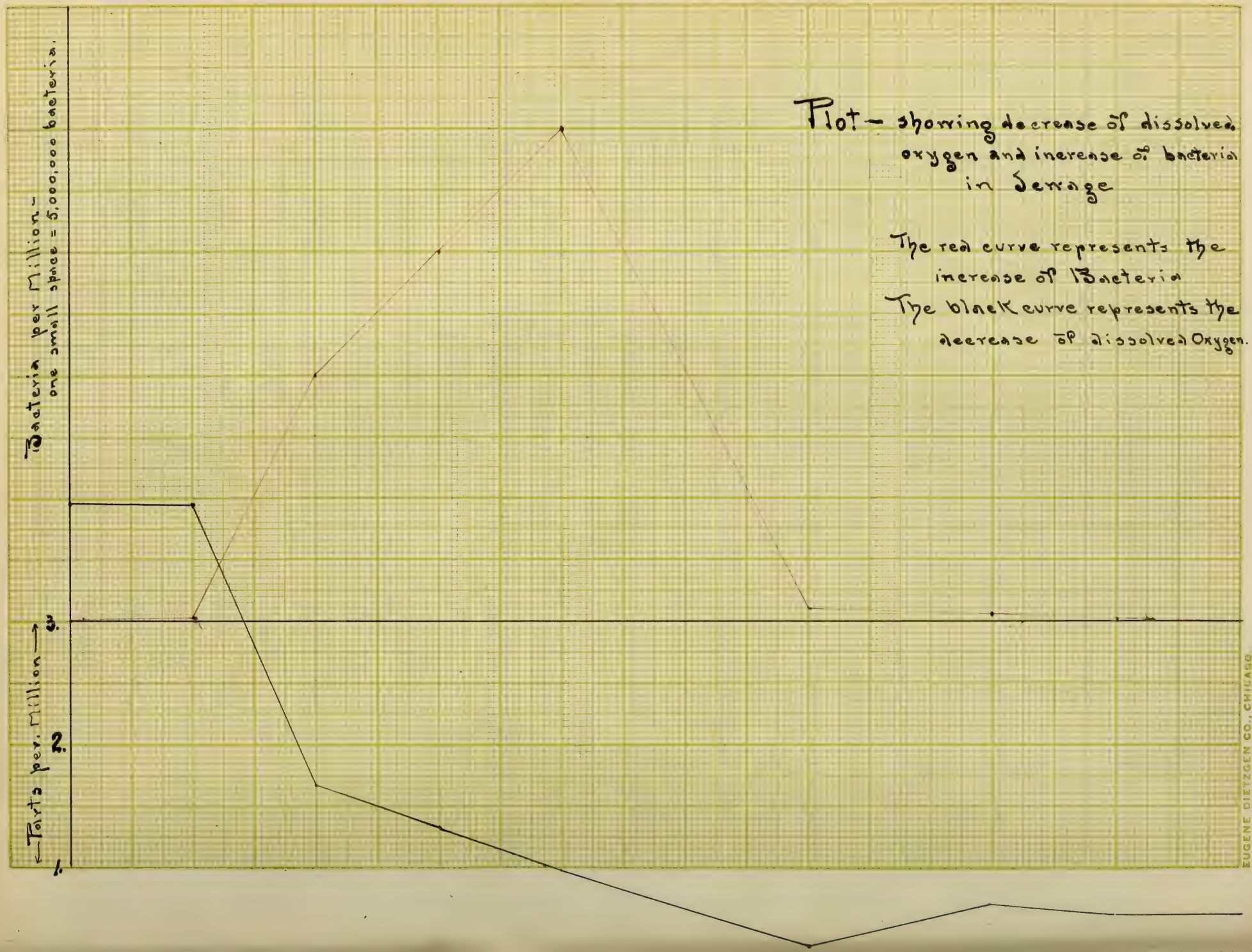
Black curve is sewage in normal condition.

50 The above experiment naturally led to the question "Does the disappearance of oxygen during the multiplication of bacteria have a connection with one another?" It is a well established fact that the bacteria in a water rapidly multiplied, consuming much oxygen in five days, and it is the object of the following experiments to ascertain the relative bearing from day to day on the water, in addition to noting the rate of disappearance of the oxygen.

On the 4th of May, eleven small flasks were taken to the Bacteriological laboratory and filled at 11 A.M. with aerated tap water, the temperature of which was 17°C. The flasks were then carefully stoppered and brought to the laboratory. One of the flasks was then rinsed and its contents aerated determined. The other flasks remaining corked was then taken to the Bacteriological laboratory, previously sterilized at 250°C. Erlenmeyer flasks for the same were kept at 37°C. 100 c.c. of distilled water was then measured into each of the Erlenmeyer flasks, and the flasks then stoppered with cotton plugs and sterilized under pressure in a steam sterilizer for twenty minutes. When cool they were removed from the sterilizer and 1 c.c. of the sewage was added to one flask, and carefully mixed with the water by shaking, 1 c.c.

of this was placed with the second Erlenmeyer flask were mixed, and 1 c.c. of this was then inoculated into four tubes, thus making a dilution of one part sewage to 1,000,000 parts sterilized water. These were melted in the sterilized tubes of "agar agar," cooled them down to nearly 40° C. and then added one tenth of a cubic centimeter of the above diluted water to each tube, mixed and immediately poured each over into the sterilized Petri dishes. One of the dishes was left with the inoculated water while the other was incubated at the room temperature. This process was repeated every day after the bacterial estimation had been determined. After a day or two standing, small colonies appeared in the agar and these were counted and the number which were found carefully noted. It was then said to [illegible] which species, the kind of color and aspect of these colonies multiplied and which diminished. The results follow:

Date of Collection of Sample	Date and hour of Examination	Temperature when Collected	Parts dissolved Oxygen per Million	Percentage Saturation	Number of Colonies per c.c. of Sewage
May. 14th.	May 14th.	17° C	3.73	37.52	2,000,000
	10 P.M.		3.73		
" "	May 15th.	"	3.70	37.22	3,000,000
	8 A.M.		3.70		
" "	May 16th.	"	1.67	16.8	200,000,000
	9 A.M.		1.67		


Plot — showing decrease of dissolved oxygen and increase of bacteria in Sewage
The red curve represents the increase of Bacteria
The black curve represents the decrease of dissolved Oxygen.
Bacteria per Million — one small space = 5,000,000 bacteria.
← Parts per Million →
3
2
1

May 14th.	May. 17th.	17°C	1.33	14.38	300,000,000
	10°° A.M.		1.33		
" "	May. 18th.	"	0.98	9.96	400,000,000
	9 30 A.M.		0.98		
" "	May. 20th.	"	0.35	3.49	10,000,000
	10°° A.M.		0.35		
" "	May. 21st.	"	0.70	7.18	4,000,000
	10°° A.M.		0.70		
" "	May. 22nd	"	0.63	6.46	100,000
			0.63		
" "	May 23rd.	"	0.63		

To summarize the results obtained from the experiments upon sewage I found that the Winter method cannot be used for sewage containing large nitrites and that, on the other hand, the Levy method gives satisfactory results. Glucose should when added to sewage encourage the activity of the bacteria contained in the water by uniting with the bacteria forms of said bacteria. The bacteria are not killed by this reagent but are quickly transformed into an inactive state, and of a suitable reagent would counteract the effect of the necessary," so added, the bacteria will, after an indefinite period again become active. Phosphoric acid is necessary for the bacterial growth in sewage, and other salts, and a water in which there is not any phosphoric acid does not,

as a rule, contain [illegible] for [illegible] and [illegible] as a part of their [illegible]

In all waters containing bacteria, if such water is enclosed in an air tight container the bacteria will multiply, and activity seems upon the oxygen dissolved in the water, until the number of aeration has become a minimum when the bacteria begin to die out. After a while we will have left only a few types which account for all in the absence of oxygen. Sewage does not, under these conditions, exhaust the activity of the bacteria in sewage and all sewages. If one contains in an air tight container loses all oxygen, that obtained from the added water, proving all dissolved oxygen in a much shorter space of time than when collated. The reason is that in the mixture the sewage from one, lacks of the oily [illegible] but to the collated the sewage was found that the necessary [illegible] always exhaust the bacterial action.

As a second test the [illegible] was conducted upon diluted and distilled water, the report [illegible] obtained with those given in Sewers.

Two 2 liter bottles were half filled with [illegible] distilled water and [illegible] [illegible]

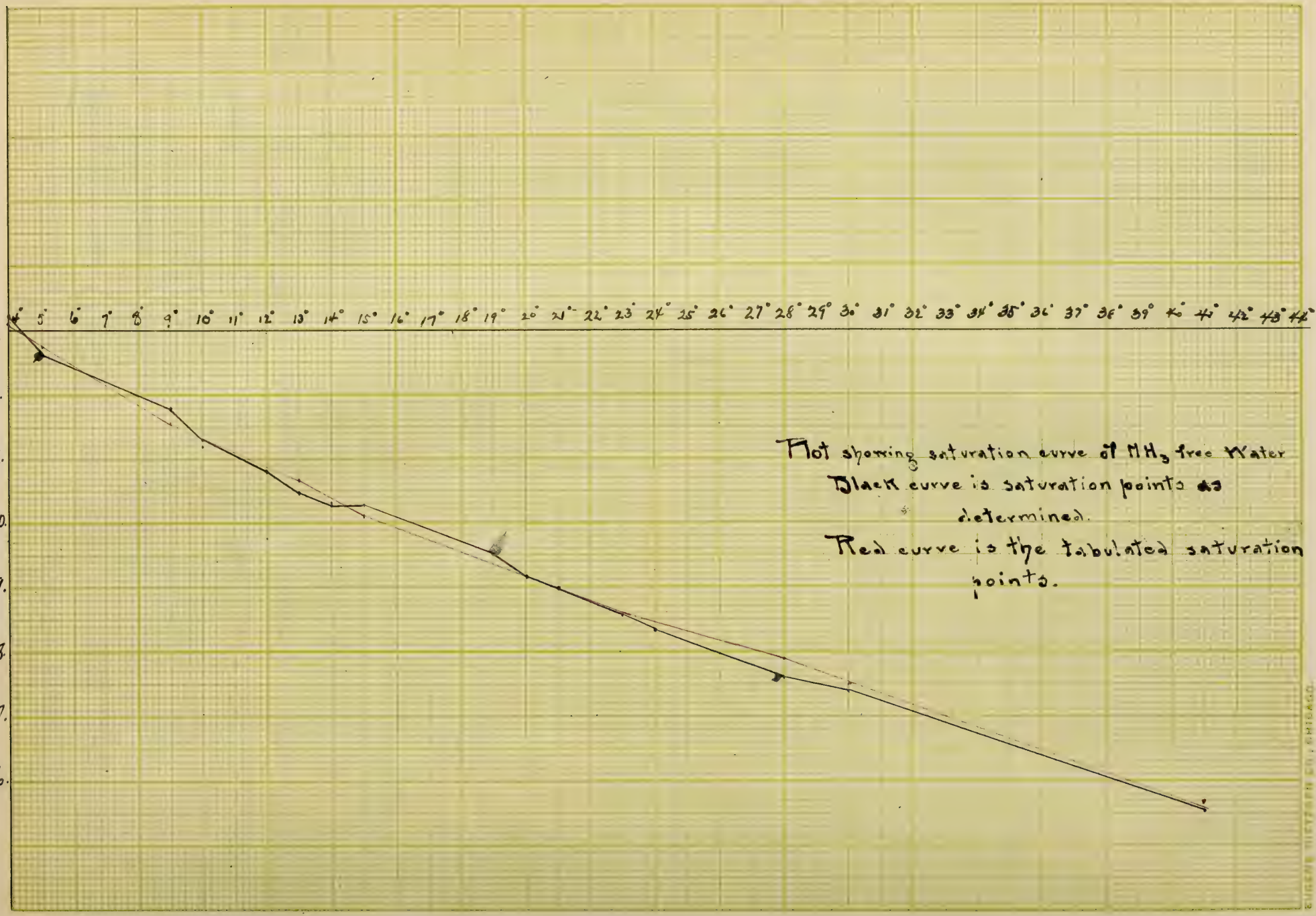
ulio, di ve ing remarks reveal limits by pour
ing one bottle with the contents of the other and divid-
ing into two portions, which are then re-saturated
[illegible] fresh air. Finally one bottle is
filled, the temperature of which the bottle is allowed to stand at room
temperature for an hour to get rid of remains of bubbles.
The water is made different temperatures by
adding either heat or ice.
The data here given [illegible]
[illegible]

Those have all been run in duplicates.

Date	Temperature Centigrade	Time Saturated	Oxygen Found	Oxygen Tabulated	Percentage Saturation.
Feb. 20th.	13° C	40 minutes	10.15	10.59	94.52
" 21st.	15° C	" "	9.6	10.14	94.74
" 23rd.	12° C	" "	9.76	10.82	90.22
" "	18.6° C	" "	9.2	9.4	97.97
" 24th.	18.9° C	" "	9.55	9.5	100.01
" "	20.0° C	" "	9.27	9.19	100.87
" 25th.	19.5°	" "	8.40	9.20	91.30
" 27th.	12.0°	" "	10.83	10.82	100.09
" "	28.0°	" "	7.63	7.90	96.58
" 28th.	9.0°	" "	11.8	11.58	101.98
" "	47.0°	" "	5.85		
" "	41.0°	" "	6.52		

Saturation of NH_3 free water cont.

Date-	Temperature Centigrade	Time Saturated	Oxygen Found	Oxygen Tabulated	Percentage Saturation
March 5th.	15°	40 minutes	10.48	10.44	100.48
" "	4°	1 "	13.23	13.15	100.63
" 7th.	5°	" "	12.62	12.78	98.76
" 11th.	10°	" "	11.30	11.31	99.91
" "	20°	" "	9.16	9.19	99.69
" 13th.	24°	" "	8.34	8.51	98.09
" 19th.	30°+	" "	7.43	7.50	99.05
" "	13°	" "	10.48	10.59	99.01
" 21st.	14°+	" "	10.28	10.30	99.8
" "	23°	" "	8.55	8.67	98.16
" 22nd.	19.8°	" "	9.2	9.2	100.00
			9.26		
" "	20.7°	" "	9.03	9.04	100.01
			9.06		
			9.07		
		Levy method			
" 27th.	21.0°	" "	9.0	8.97	100.33
" "	"	Winkler method " "	8.5	"	94.76
" 28th.	22.0°	Levy method	8.84	8.84	100.00
			8.84		
			8.84		
" "	"	Winkler	8.33	8.84	94.32
			8.32		94.11
			8.34		94.34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Plot showing saturation curve of NH_3 free Water
Black curve is saturation points as determined.
Red curve is the tabulated saturation points.

62. The results [illegible] aerated water were quite satisfactory, nearly all of them being but a small amount below the calculated amount, and in accordance of the Levy & Winkler method for these standard ammonia free waters showed the results obtained from the Levy method about 1.5 parts more than of the Winkler.

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